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WM. SPRARAGEN
Editor

AMERICAN WELDING SOCIETY

EDITORIAL AND BUSINESS OFFICES

33 West 39th St.
New York, N. Y.

FALL MEETING

The fall meeting of the American Welding Society will be held in Boston during the week of September 21.

As in previous years the meeting will be arranged in conjunction with a welding exhibition held jointly with the American Society for Steel Treating. A number of other societies are planning to hold meetings in Boston during this week.

TECHNICAL PAPERS

The Meetings and Papers Committee are now at work on the fall meeting program and, also, on a list of suggested papers for local section meetings.

Every member of the Society who is willing to present a paper should notify headquarters of the availability of such material giving information as to the title of the paper and a sentence or two describing what the paper will be about. Preference as to section or national meeting for the presentation of such papers should also be stated.

The Meetings and Papers Committee also solicits papers for publication in the Journal of the Society regardless of whether they are presented before local sections or national meetings.

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JOURNAL OF THE AMERICAN WELDING SOCIETY

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Fall Meeting Program

The Meetings and Papers Committee of the Society have practically completed their program for the Fall Meeting. It can be stated without exaggeration that this promises to be without exception one of the greatest meetings ever held by the A. W. S. More than five hundred members and guests are expected to attend the annual dinner of the Society.

The meeting will open formally on Monday, Sept. 21, with the meeting of the Structural Steel Welding Committee. A summary of a report of the results of a large series of tests made by this committee will be presented at this meeting, as will, also, a discussion of the additional investigations to be undertaken. Registration facilities will be provided throughout the week commencing Monday morning. The Board of Directors' meeting will be held on Monday evening.

On the days following there will be six technical sessions at which some fourteen technical papers will be presented covering many important phases of welding and cutting. All processes of welding will be covered, including manual and automatic applications. There will be special papers on the welding of non-ferrous metals, corrosion resisting steels, welding of machinery parts, annealing, welded piping, welding in ship construction, structural steel, and other general applications.

A more detailed program will be published in the next issue of the JOURNAL. In order to stimulate discussion, papers will be published in the September issue of the JOURNAL in advance of the meeting.

On the afternoon of Tuesday there will be an inspection trip and outing. The annual banquet and dinner will be held on Thursday evening. Special attention has been given this year to the entertainment of the ladies.

BOUND VOLUMES

Bound volumes of the Journal for the year 1930 are now available in attractive imitation black leather covers. This volume contains a wealth of information on all phases of welding. Price per copy $5.00. Subject and Authors' Indices permitting easy reference are included. A few bound volumes for the years 1924-to-date are still available at $5.00 per copy. Inasmuch as there is only a limited supply available it is suggested that orders should be placed at once.

Standards, Specifications and Codes, Published by American Welding Society

Supply of following Bulletins is limited. If you desire any of these, place order at once.

	Price
Standard Tests for Welds	25c. each
Welding Wire Specifications	25c. each
Investigations on Welded Pressure Vessels	50c. each
Training Course for Oxy-Acetylene Welders	25c. each
Training Course for Electric Arc Welders	25c. each
Applications of Arc Welding to Ship Construction	50c. each
Fundamentals of Gas Welding	50c. each
Fundamentals of Resistance Welding	35c. each
Fundamentals of Thermit Welding	50c. each
Metallurgy of Welding Wire	25c. each
Code for Fusion Welding and Gas Cutting in Building Construction (1930 edition)	25c. each
Specifications for Test Specimens, Their Preparation and Testing	50c. a set
General Procedure Control for Gas and Arc Welding Aircraft Joints (Journal A. W. S., December, 1928)	50c. each
Progress Reports 2 to 7, Welded Rail Joint Committee	50c. each
Report on Welding and Cutting Nomenclature, Definitions and Symbols	50c. each

SECTION ACTIVITIES

BOSTON

There follows a summary of the meetings held by the Boston Section during the 1930-31 season and the subject of the papers presented.

AMERICAN WELDING SOCIETY, BOSTON SECTION, SEASON 1930-31

Date 1930	Location	Subject	Attendance
Oct. 24	Austin Hastings Co., Cambridge, Mass.	Welding of non-ferrous metals	146
Nov. 14	Thomson-Gibb Electric Welding Co., Lynn, Mass.	Seam welding — Projection welding. Welding of motor frames	64
Dec. 19	Linde Air Products Co., Engineering Society's rooms	Panel heating	100
1931 Jan. 28	Joint meeting Boston Society of Civil Engineers, Chipman Hall	Boston Edison welded office building	200
Feb. 20	Lincoln Electric Co. at plant of Harvey Steel Co., Allston	Fleet welding or shielded arc process	200
March 20	Watertown Arsenal	Use of electric welding at the Arsenal. (Afternoon meeting)	40
April 15	Joint meeting Engineering Societies of Boston, Tremont Temple	Lighter than air craft, presented by Mr. Jacobs of the Goodyear Tire & Rubber Co.	2,500
			3,250

The Boston Section has had a very successful season during 1930-1931, with a program of meetings in which many varied and interesting subjects were presented. The enclosed summary of the season's meetings will probably be of interest to members of the Society.

The plans for the Fall Convention and Exhibition to be held in Boston, September 21 to 25 inclusive, are rapidly being formulated. In addition to the interesting exhibits to be displayed at Commonwealth Pier, and the varied papers to be presented at the technical sessions, there will be an attractive entertainment program for the members, their ladies and friends.

It is expected that a boat trip down Boston Harbor will be included in the program. Leaving the pier the latter part of the afternoon, those taking the trip will be able to see points of interest as the boat goes down the harbor. The return trip being made after dark, the beautiful moonlight sail will end a pleasant evening's journey.

NEW YORK

In concluding my term of office as Chairman of the New York Section I have the honor of making the following report of the Section's activities during the past fiscal year.

Meetings were held as follows:

Date of Meeting	Joint Meeting	Attendance
1930		
May 20	Regular section	120
June 14	Inspection trip to Westinghouse Electric & Mfg. Co.	360
Sept. 16	Inspection trip to Westinghouse Lighting Inst.	180
Nov. 18	Building Code Comm.	700
Dec. 16	Regular section	125
1931		
Jan. 22	American Society of Mechanical Engineers	300
Feb. 24		50
March 9	American Society for Steel Tr.	350
May 23	Inspection trip—Brooklyn Navy Yard	450
		2,635

Our activities this year indicated a very popular trend toward joint meetings with interested societies, and especially toward inspection trips. Very constructive work has been done in connection with the former by the Section's Joint Meetings Committee, under the chairmanship of H. H. Moss, and the Inspection Trip Committee, of which Charles Kandel was chairman.

T. C. Fetherston,
Chairman New York Section.

LOS ANGELES

The regular monthly meeting of the Los Angeles Section of the American Welding Society was held at the Engineers Club on Tuesday, June 16.

There were thirty members and fifteen guests present.

Mr. Martin brought up the question of machining or sand blasting the edges of plates to be flash welded. It was the consensus of opinion that such a procedure was necessary to secure desirable characteristics in the weld.

Mr. Page, of the California State Boiler Inspection Commission, gave his ideas regarding a tentative code for state or national qualification of welders, to apply only to men welding on pressure vessels. This tentative code will be submitted to the Society for consideration and for criticism.

Turner Smith prepared a very interesting and valuable summary of the new Boiler Code as applied to Unfired Pressure Vessels, and led a discussion in which the salient features of the new code were pointed out.

PHILADELPHIA

There is given below a complete review of the meetings of the Philadelphia Section, held during the 1930-31 session.

		Attend.
May 19, 1930	Mr. W. B. Miller, Union Carbide & Carbon Research Laboratories, "Oxy-Acetylene Welding of Commercial Chromium Alloys." Mr. R. D. Thomas, of R. D. Thomas & Co., "Arc Welding of Stainless and Corrosion-Resistant Steels."	75
Sept. 15, 1930	Mr. Charles Kandel, General Manager, Craftsweld Equipment Corporation, read paper by Commander Edward Elisberg, U.S.N., "Development of the Elisberg S-51 Underwater Cutting Torch." Showed motion pictures covering the activities in the raising of the U.S.S. "S-51." Talked on "Industrial Projects on Which the Elisberg Underwater Cutting Torch Has Been Used," and exhibited cutting outfit and diving rig.	80
Oct. 20, 1930	Mr. John Reed, Chief Electrical Engineer, Bethlehem Steel Co., Steelton Plant, "Illustrations of Repairs to Steel Plant Machinery Done by Welding," and Mr. H. J. Bowles, Welding Supervisor, Bethlehem Plant, Bethlehem Steel Co., "Instruction and Qualifications of Welders."	95
Nov. 17, 1930	Mr. J. T. Whitney, President, Whitney Engineering Co., "Planning, Specifying and Supervising of a 14-Story Office Building in Boston." Mr. J. L. Faden, Industrial Engineer, The Edison Electric Illuminating Co., showed motion pictures of the work. Mr A. G. Leake, President, Leake & Nelson Co., Bridgeport, Conn., spoke of the welding.	150
Jan. 19, 1931	Mr. W. R. Ost, Engineering Department, Air Reduction Sales Co., New York, "Welding of Distribution Pipe Lines" and "Improved Methods of Welding on Transmission Pipe Lines and Compressor Stations."	95
Feb. 16, 1931	Messrs. G. Exley, Donald J. Riddell and C. I. MacGuffie, of the General Electric Co., "Recent Developments in Automatic Arc Welding" and "Automatic Atomic Hydrogen Welding."	110
March 16, 1931	Mr. James W. Owens, Director of Engineering, Welding Engineering and Research Corporation, "Residual Stresses."	65
April 20, 1931	Mr. J. A. Davis, South Philadelphia Works, Westinghouse Electric & Mfg. Co., "Welding as Applied to Marine Equipment."	60
		730

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the BULLETIN.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be addressed to the number indicated in each case and mailed to the Society headquarters.*

SERVICES AVAILABLE

A-134. Arc welder desires position. Have recently graduated from the welding school of the General Electric Company and am familiar with Arc, Automatic and Atomic Hydrogen Welding. Have also had experience in steel erection.

A-135. Experienced gas welder desires position. Has worked for Staten Island Shipbuilding Company; C. W. Hunt & Company mining app.; Mergenthaler Linotype Co., machinery work; Marcus Cont. Co., subway construction, and various subway jobs.

A-136. Position desired as welding engineer having had five years' operating experience in all phases of welding, two years assisting research engineer and five years' sales engineering experience. Will go anywhere.

Discussion Papers Presented at Annual Meeting, A. W. S.

WEDNESDAY MORNING SESSION

Discussion Paper on "Welded Boilers for U. S. Navy Scout Cruisers," by Mr. J. C. Hodge, Babcock & Wilcox Co.†

CHAIRMAN OBERT.

THE older members of the Welding Society are, of course, familiar with the attitude which the authorities have shown toward the welding of boilers. For a great many years the use of the term "welding" in connection with boiler construction has been a signal for trouble. It has been frowned upon by the authorities for as long as we have had boiler codes. The recent very rapid developments in welding, of course, have changed that situation very noticeably and it is a matter of great pleasure to everybody in the welding field to realize what has been transpiring in the past few years in the way of improvements in the welding of thick plates that have warranted the recognition of welding for boiler construction.

I think most of the members of the Society are familiar with what has developed along the lines of the welding code, as referred to by our president in his report this morning. In several issues of the Welding Society Journal, these proposed new codes for welded boilers and welded pressure vessels have been published. The most recent of these were in our January and March issues. So you have all had the opportunity to know how close we are to the accomplishment of an actual welding code.

In view of such development I think we are very fortunate in having a paper this morning which will outline to you what has been accomplished in the introduction of welded boiler drums in the United States Navy. The author of this paper is a man who has been one of the pioneers in the development of the application of welding to steam boilers. He has been connected with the Barberton Works of the Babcock and Wilcox Company where some very interesting development work has been carried out, and I am quite sure he will give us a very interesting presentation in this paper. I take great pleasure in introducing to you as the author of the first paper entitled, "Welded Boilers for U. S. Navy Scout Cruisers," Mr. J. C. Hodge.

(Mr. Hodge read his prepared paper illustrated with slides.)

I consider this a very remarkable paper, gentlemen. If we could have some of the old-time objectors to welding appear here today we could have a very interesting discussion of this paper. Unfortunately, however, I do not see very many boiler men in the room, I personally invited a number of prominent boiler manufacturers to attend, some that are objecting to some phases of the specifications that are under discussion, but unfortunately they have not appeared.

This paper signifies that the specifications which Mr. Hodge has described have been worked out on such a satisfactory basis that one of our important Government departments has seen fit to order boilers under them. This is a remarkable accomplishment. That department, as well as the other Government departments, has adhered so strongly to riveted, seamless and forge-welded construction that anything in the line of welding has heretofore been simply out of the question. Now, however, a specification has been submitted to them, as Mr. Hodge outlines, that has proved satisfactory, and a large number of the boilers are being ordered thereon.

I think it is now appropriate to have some expressions of opinion from those who are interested in welding, as to what you think of these specifications. The paper is now open for discussion.

MR. J. C. LINCOLN (The Lincoln Electric Co.): There are two questions I would like to ask. In one of his photographs a defect was shown and in the macrograph of the same section indicated that the defect which he spoke of was simply due to the fact that the weld had not been made deep enough so the two cross sections intersected. How thick was the parent metal and what reason if any can be assigned for not getting the weld deep enough so that the two cross sections intersected.

The second question I would like to ask is the detail of how that Charpy test is made, together with the size of the samples on which the test is made.

MR. HODGE: The x-ray or radiograph of this welded joint (Plate No. 7) was not placed in the paper to show up the defect in the welding process. This was included principally to bring out the fact that the x-ray method of examination will disclose a minute fissure or crack. If you will examine the macrograph of this joint or the macrograph of weld for Plate No. 7, the fissure represented by the unfused junction of the two plates in the approximate center of the joint was very very small and of inappreciable width and yet this fissure was disclosed on x-ray examination.

The thickness of the plate was ¾ in.; the length of the crack was 1/16 in., so that we find the x-ray method detecting the presence of a fissure representing a length of 1/16 in. in a total thickness of ¾ in.

The Charpy impact test specimen is relatively small. It is of square cross section, .394 in. x .394 in., and is notched on one side, the form of the notch being usually a keyhole. The specimen is supported on each end and the specimen is broken by a single blow from a heavy swinging pendulum which strikes the specimen back of the notch, thus breaking the specimen through its minimum section.

MR. LINCOLN: How is the measurement of the foot pounds obtained, by the weight and distance from which the weight falls?

MR. HODGE: The swinging pendulum or hammer strikes the specimen at the bottom of its arc. As long as no obstruction is present in the swing of the hammer, zero pounds will be indicated when the hammer swings over to the maximum position on the other side of its arc. However, as soon as an obstruction is placed in the path of the swinging hammer, energy is absorbed in breaking that obstruction. The hammer does not rise to as high a position and the total foot pounds of energy required to break the specimen is indicated on a scale.

MR. LINCOLN: What is the distance between the supports in which the sample is placed?

†Paper published in April, 1931, issue Journal of the A. W. S.

MR. HODGE: That distance may vary considerably, it is usually about an inch and one-half.

MR. LINCOLN: The hammer then passes between the two supports?

MR. HODGE: Yes.

DR. ST. JOHN (St. John X-Ray Service Corp.): Mr. Hodge's paper has brought out very clearly the importance of some means of verifying thoroughly well-established procedures. I think that there is no question about the quality of the specification for the manufacture of the Navy drums that have been discussed. There is no question as to the quality of the weld metal that is being deposited. It is shown by tests the specifications are good, but with the best of specifications, with the best of weld metal and as far as the manufacturer knows the best of conformity to the specifications, nevertheless one drum out of twenty-four showed a distinctly intolerable condition. That is the point that I have been making in season and out of season with respect to the desirability if not the necessity of a means for the manufacturer first of all to assure himself that material made in accordance with his specifications actually is in accordance with those specifications, and, secondly, for the manufacturer to be able and willing to show to the buyer that the material which he asserts to be worthy of his name is really worthy of that name. There isn't one man here, or there isn't one man in the manufacture of pressure vessels who would willingly sign his name to a check when he didn't have the money in the bank, and it seems to me that when a manufacturer of vessels for critical pressure service says, "I know we make good pressure vessels; we have got a fine specification and we have excellent workmen," but does not use all means that are available to assure himself that his specification is being followed, is coming perilously close to signing a check on the bank that doesn't have enough funds to his credit.

Leaving that subject for a moment, I would like to point out that unintentionally Mr. Hodge has been very unfair to x-rays in saying that they are able to detect a cavity 1/16 in. thick in a piece ¾ in. thick. That is quite true. Likewise, it is perfectly able to detect a cavity 1/16 in. thick in a thickness of 2 in. or 2¼ in. or even of 3 in. In fact, reference to the proposed specification will show that the x-rays must be of such a character that they are competent to detect a defect which is 2 per cent of the thickness of the material examined.

In connection with the examination of welded materials, we have done a great deal of work in our laboratory. As far as I can remember at the present time with the single exception of one test, a plate which was submitted to us prior to the examination of any x-ray results on other work from a given source, we have never yet found that the material is exactly living up to specifications. The welder always has something to learn, and that is an aspect that it seems to me is worth considering in connection with the whole x-ray proposition—the education of the welder and the man who tells the welder what to do.

CHAIRMAN OBERT: Dr. St. John's remarks are very appropriate at this time because the use of the x-ray in these specifications and also as proposed by the Boiler Code Committee for a non-destructive test of welds, is going a long way to induce the various Government departments to accept welding for boilers. There are, unfortunately, many objectors to the x-ray process as for this purpose. I am sorry that some of the boiler manufacturers that were invited to attend this session, aren't here to voice their objections. No matter what we may think about the x-ray or the idea of a non-destructive test, however, the provision in these welding rules for determining what is inside the weld is one of the arguments that is opening up welding to the authorities and bringing them to feel that as long as the art has advanced to the stage where the quality of the welding is determinable, they are willing to accept weld construction without limitation.

It is rather surprising that we are getting so far along in this session without some criticism of the position which our Society and the A. S. M. E. Boiler Code Committee has taken with regard to the x-ray test. If I understand correctly, there are some members of the Welding Society who are opposed to the x-ray method of test. I would like very much to have that feeling voiced if there is anybody here who feels so inclined. Mr. Owens, what do you have to say about this x-ray situation?

MR. JAMES W. OWENS: (Welding Engineering and Research Corporation): Mr. Chairman and Gentlemen: Mr. Hodge's paper is to me outstanding in that it clearly indicates the remarkable progress welding is making in the Bureau of Engineering of the Navy and Industry in general. Furthermore, it should be noted that the Navy Department's order for these boilers was obtained by the manufacturer submitting rigid specifications for their construction, and that there was included in these specifications the use of a non-destructive method of testing the welded joint, the efficacy and necessity of which was clearly demonstrated in their manufacture, and as shown, if the x-ray had not been used, one of these boilers would have been put in service with a defective weld.

Some manufacturers have expressed their opposition to the use of x-ray, and I hope that the proof of its necessity as submitted by Mr. Hodge will allay any objections to its use, particularly as the proposed code does not require x-raying of every vessel. Indeed, it would be an absurdity to include such a requirement in any code. The proposed code as it now stands would only require the use of the x-ray, or other suitable non-destructive tests, for those classes of vessels where serious damage to life and property might occur if there were failure. Furthermore, the Boiler Code Committee has taken a sound economic position by allowing the manufacturer a higher joint efficiency for joints which are x-rayed, thus permitting the manufacturer to reduce the shell thickness and therefore the cost of the vessel constructed.

I am now looking as an outsider at the enviable position of the Babcock and Wilcox Company for increasing their business by having put themselves in a position to assure purchasers that they are obtaining a sound and serviceable product. Gentlemen, if this company is able by means of the x-ray to induce customers to purchase their vessels, probably even at a higher cost than those of a competitor who has not this equipment for testing, the Boiler Code Committee will not have to require or even to suggest to manufacturers that their vessels be x-rayed or tested by some other equally satisfactory method. This is exactly what is going to happen, and the manufacturer who equips his plant with the available means to scientifically test welds is going to get business.

CHAIRMAN OBERT: Mr. Owens brought out one very important point that I would like to make clear. The Boiler Code Committee is not limited in its deliberations solely to this x-ray non-destructive test. It is considering the gamma ray, which is the use of radium, the x-ray and the magnetic method of analysis. At the last meeting of the Boiler Code Committee the magnetic analysis method of the Ferrous Magnetic Company of New York City was demonstrated and the Committee is of the opinion that it has promise

The Westinghouse people have also developed a magnetic method of analyzing welded joints. A description of their method was published in one of the issues of the Welding Society Journal last fall. The Committee is looking with favor in that direction and it may be said that any suitable magnetic test which when applied will give the desired results, will be satisfactory to the Boiler Code Committee. The outstanding feature of the x-ray and the gamma ray is that they constitute the method of non-destructive test that is at the present time the farthest in advance. The x-ray has been worked out to a practical point and is being used by various companies for analysis of ferrous metallic structures.

Is there any other discussion on this paper by Mr. Hodge?

MR. S. S. SCOTT (U. S. Navy Department): It is with a great deal of interest that I listened to Mr. J. C. Hodge's paper and also to Mr. Owens' remarks here this morning, particularly from the standpoint of being affiliated with the New York Navy Yard and of the fact at the present time we are constructing the New Orleans cruiser over at the New York Navy Yard. With reference to Mr. Hodge's paper I wish to state that about 1918 the research department of the Army started x-ray experiments in the Watertown Arsenal upon defects in gun forgings. The object of these tests were to actually put into service guns that were absolutely free of all defects. Thorough and expensive tests were made at the Arsenal on material up to 3½ in. in thickness and the results obtained from these tests had a great deal to do with the advancement of the x-ray methods of today.

We observe now, according to Mr. Hodge's paper, that the Babcock & Wilcox Company have shown that they can use x-rays to satisfactory results on the welds made as pressure vessels, and it is with a great deal of interest we listen now to this particular case brought up here, for the reason that we always wished to have a weld free of all defects, and although Mr. Hodge stated he has examined 24 boilers for the Navy and only one failed, certainly proves the point that welding is fast perfecting itself in the fabrication field today.

A great deal of the success of the Babcock & Wilcox Company has been in the technique of welding the material which they were using, especially material for the boilers and the material for the electrodes. Mr. Hodge has not gone into any details on his materials that he used for electrode and what particular flux for the rod. I wonder, Mr. Chairman, if it would be out of order if Mr. Hodge could enlarge a little upon the nature of his electrode and the coating that he used.

CHAIRMAN OBERT: Mr. Hodge, is there anything which you can say about that?

MR. HODGE: That question arises every so often. I am not in a position to give you any details of the process; it is not a question of trying to maintain a mystifying atmosphere of secrecy; anyone can duplicate the results by sufficient investigation in a very short time. It is only a question of the economics of the general situation. I will be glad to give you any data which we have on welded pressure vessels other than details of the welding process.

CHAIRMAN OBERT: There is an interesting phase of this welding code situation that comes up in connection with the subject here under discussion. When the Boiler Code Committee started some years ago on the proposition of a welding code, it undertook to develop welding procedures, that is, specifying the details that should be followed in all parts of the welding process, including preparation of the edges to be welded, the kind and type of rod for gas and electric welding and all those related matters. It found, however, in connection with this development so many new methods of welding in use, most of which are electric with a coated rod specially designed by the manufacturers to maintain a gaseous atmosphere around the arc, that there was great resistance on the part of these companies to reveal to the public all they accomplish. Therefore the Code Committee has entirely revised its plan and is specifying the results, rather than the method of getting the results. This seems to be in harmony with the way in which the welding industry is developing at the present time, and in all probability with so many proprietary processes and proprietary rods in use, it is the only fair method to follow. It is a matter of great interest to the officers of the Welding Society to realize that this welding code could be developed by specifying the result. The non-destructive test, of course, is one of the essential features.

PRESIDENT DOYLE: Mr. Owens has made a statement that many members of the Welding Society objected to the non-destructive test, especially relating to the x-ray. I hope that no one here is going away feeling that the Welding Society objects to the test for the reason that they are afraid to have uncovered defects in welding. The principal reason for any objection from the standpoint of the Welding Society is because of the various letters that have come in from the members, manufacturers, protesting against the x-ray or other such non-destructive tests. Not because they were afraid of their product, but because of the expense to which they will be put by having to put in x-ray apparatus or to lease it or to go to what other extremes are necessary to have these tests passed.

It now gets down apparently to a broad question of who is going to pay for it. I will confine myself to one instance. A letter came in from a rather prominent manufacturer not more than a month ago protesting vigorously against the x-ray and the necessity for using it. Not more than a week ago I talked to the president of that same concern. He said, "I don't know. Maybe we are not so opposed to x-ray. We are not afraid of our material. We have canvassed our trade and we find that they are willing to have us pass on to them the expense of making these tests. If they are willing to pay for it, we are willing to put in the equipment and do it." I believe you will find as time goes along that that is the general condition as far as the Welding Society is concerned, not that we object to it but we do object to making a proprietary method and throwing all the business or attempt-

ing to throw all the business into the hands of one or two manufacturers. When manufacturers are able to pass along the expense—fine—they are willing to adopt x-rays or any other means and the Society is going to sponsor them.

DR. ST. JOHN: I am very glad that point has been brought out because it gives me a chance to get off on one of my pet hobbies and that is that such novel methods of testing which are primarily for the insurance of the buyer against loss, but secondarily for the assurance of the reputation of the maker against damage, are primarily to be done at the expense of the buyer. For some six years now I have been conducting an x-ray testing business and practically the entire cost of the work that I have done has been borne by the buyer more or less at his own request, and very frequently from the point of view that "we want to pay for it because we want to be able to reject the material on the recommendation of somebody whom we are paying."

I don't know that that is going to be the situation that is going to develop in welding, but it seems to me that it is exceedingly sound point of view. Namely, that if a given type of non-destructive test is specified, in the first place it means that all manufacturers who want to go into that line of business have got to pay for that testing or have got to pass it on to their customers. In the end they are going to pass it on to their customers anyway.

If Bill Jones buys welded boilers, x-ray inspected, and Sam Smith buys welded boilers that are not x-ray inspected, Bill Jones is going to pay extra for his x-ray inspected boilers in the long run and that is as it should be, and it seems to me that a very reasonable and economic point of view is that if, as and when the code or the customer's engineers specify that x-ray or other types of non-destructive tests shall be carried out, that he is entitled to have them, if he wants them, and as I have said in the other place he is entitled to pay for it. In the long run he is probably going to pay for it anyway. Most of them would rather see it in the bill as so much of a premium for so much sort of insurance than have it appear in general overhead, the same as the salesman's new overcoat.

CHAIRMAN OBERT: To supplement Dr. St. John's remarks, it may be said that the non-destructive tests will be called for in the proposed new welding rules for pressure vessels only where the thickness exceeds 1½ in. The proposal as it relates to steam boilers is for all welded boiler drums, but in the pressure vessel field there is provision for avoiding the cost of the non-destructive tests on vessels that do not exceed 1½ in. in thickness. Thus, as Mr. Owens has pointed out, this non-destructive test is being considered only in connection with vessels and boilers that are intended to be subjected to the most severe type of duty.

MR. A. M. CANDY (Westinghouse Electric & Mfg. Co.): Mr. Obert was obliged to cut us just a little bit short on Mr. Hodge's paper, and if I can take just a few moments I am going to refer back to his paper again. I don't want to be put on record as opposing the question of x-ray testing whatsoever. My only attitude toward x-ray testing, which is probably due to lack of familiarity with it, is that it seems to me that it takes considerable judgment in reading the x-ray photographs to assure yourself just what is happening.

I expect Mr. Hodge, when I make that remark, will probably feel toward me like I have felt toward other individuals in the past when they have asked, "How do you know when you have a good weld? We can tell about a riveted joint but we don't know when a weld is good." We who are familiar with welding and welding processes felt if we could watch the operator and examine the weld metal we could determine with a reasonable degree of accuracy the quality of the weld. Probably people who are familiar with examining x-ray pictures feel the same way about it. But as an outsider on the other side of the fence an x-ray photograph of a weld leads me to believe that I would have to have an awful lot of practice in looking them over to determine definitely just how good or bad the weld is of which the x-ray is taken.

I want to bring out another point in that connection and that is this: What I am thinking of primarily is quantitative results rather than qualitative results. About a year ago I happened to go to Watertown Arsenal and Colonel Dixon and his associates showed me some work they have been doing on stereoscopic x-ray. They showed me some photographs taken of welded connections; set them up on the machine and you could look into the mirrors and get your depth and it seemed to me with that layout you could soon calibrate yourself and make some pretty accurate predictions as to just how much of the total volume of weld metal was really weld metal and how much of that volume was slag inclusions, gas pockets, etc.

It struck me as being much more quantitative than merely the flat photograph. Of course, we appreciate those things can't be as yet shown on the screen, but it seemed to me that this was a real step in advance. I was wondering as I sat here this morning if it wouldn't be possible for some one who is an expert at x-rays and x-ray photography and also a bit of a hand with vacuum tubes if he couldn't work out some arrangement so that x-rays would fall on a photoelectric cell and you could get a meter indication as to how deep a defect is. I don't know whether that is possible or not. If it is it would be another step in the right direction in giving us even more accurate method of determining the character of the joints.

There is just one question I would like to ask Mr. Hodge and that is this: Out of the 24 shells that were welded, the x-ray showed one to be defective. I am wondering if he made any tests of sections through that defective joint to calibrate the percentage of actual strength of the joint compared with his x-ray so he would get some real calibration of the x-ray photograph.

MR. HODGE: The one longitudinal joint which proved defective on x-ray examination was entirely machined out and the entire joint re-welded. This was a production job and we could not remove test plates to examine the welded joint and so scrap that plate. It would have have been a rather interesting piece of investigation, but the same results can be obtained by investigating sample welds which show defects under x-ray examination.

Regarding the x-ray examination of welded joints, I think the entire question boils down to three questions:

First, are defects such as porosity, slag inclusions, cracks and fissures dangerous to welded joints in pressure vessels? The answer of engineering opinion to that first question will undoubtedly be "yes."

The second question is will the x-ray method disclose those defects? I think technical opinion will answer "yes."

The third question is can it be done economically? I think our figures of 50 cents per foot of joint for x-ray examination of 1-in. thick plate is a very reasonable item in the cost of a welded pressure vessel. On a welded pressure vessel costing $10,000 the cost of x-ray examination will be approximately $150. This will vary according to the size, shape of the drum and the number of drums requiring x-ray examination.

MR. LINCOLN: What does this 50 cents per foot include? Does it include the cost of film and the cost of extra time?

MR. HODGE: This estimate includes the cost of the machine, the cost of the film and the cost of labor and overhead on the labor in the exposure of the films. The x-ray machine is operated by two men, one man in charge of the machine, who is not necessarily an x-ray expert, and an assistant. We figure the cost of the labor of those two men as being approximately $3.50 to $4 per hour, including overhead. On welded pressure vessels similar to the Navy boiler drums we can expose 30 ft. of joint per hour.

MR. H. A. WOOFTER (Swift Electric Welder Co.): I can see great possibilities in the testing of welds by the method Mr. Hodge outlined. However, some time ago when I was at one of our leading universities, a gentleman attempted to give a demonstration of testing welds by means of the stethoscope and hammer. The results were by no means all that could have been desired and in fact were very discouraging, and I heard some very unfavorable comments made regarding the undependability of the results. In that method the human element would enter very largely because no two men have ears alike; no one man has two ears alike. Furthermore, in the blows from the tapping of the hammer, no two blows would be alike. The variation in the human equation would be very large indeed.

I assume that many of you are familiar with the method devised by the late Mr. Sperry, who invented the gyroscope. The work he did was for the railroads to test the general structure of steel rails. He devised a scheme using radio frequency and one or two other things in connection with it by which he could test rails and then went a step further and placed the device on a car that could be run along the rails at a rate of eight miles an hour and if there was a defect in any rail this machine would squirt a little streak of red paint at that particular point. In checking it up in hundreds of cases they never found that the machine made a mistake or lied a single time. It seems to me something like that might have wonderful possibilities in testing welds.

CHAIRMAN OBERT: Possibly Mr. Hodge can give us some thoughts on that. I believe the Babcock & Wilcox Company have tried out the Sperry process.

MR. HODGE: About eight months to a year ago we investigated the Sperry method of examining welded joints of pressure vessels. This was done in cooperation with the Sperry Development Company. In a paper I published in the fall of last year I discussed some results and gave a brief summary of the results we obtained with the Sperry apparatus, which showed that the Sperry apparatus will pick up defects in welded joints. The only objection as I see it is trying to sell people the idea of examination by non-destructive tests similar to the Sperry method.

I don't know whether you are familiar with the principles of the Sperry method or not. This represents a welded drum with a longitudinal joint. A heavy D.C. current is brought in to the welded joint, passing in through one side, through the welded joint and up through the other brushes. As long as there are no defects in that welded joint there will be a uniform current density through this joint and also a uniform magnetic flux up in this region. As soon as there is a defect present within that welded joint, there will be a distortion of the current flux and a distortion of the magnetic flux in this region. They have a little balanced core unit up here and that remains in balance as long as the magnetic flux is uniform. As soon as there is a distortion of the magnetic flux, this little coil is thrown out of balance; the amperage set up in this coil is used to operate a set of relays which operate pens and cause a straight line to be drawn on a piece of paper by the pen as long as no defect occurs in the weld. As soon as there is a defect in the welded joint, there is an indication or a departure from that straight line.

Now the objection to this method and the reason why we concentrated on the x-ray method in preference to this was trying to sell people the idea that this job represented a defect. It requires a little imagination. While the operator of this machine would know that this departure from the straight line meant a defect in the weld, it would be rather hard to sell the man who is not familiar with the machine the idea that this represented a serious defect and the welded joint should be scrapped.

In comparison, take the x-ray film and instead of this mere departure from a straight line, there is a definite picture. It is something that can easily be visualized with an identifying number right opposite corresponding with a mark on the drum.

The Sperry apparatus gives excellent results. We have detected defects in welded joints with the Sperry apparatus in the neighborhood of a quarter inch square, which would represent about 0.025 sq. in. in a total thickness of 2 in. I think if you refer back to that previous paper that was published in the Journal you will find a summary of our experiments.

CHAIRMAN OBERT: Mr. Carter's comments deserve the comment that the large number of vessels that he speaks of are generally in the smaller sizes and in the lesser thicknesses of shell plate. As far as that class of vessel is concerned, it is not proposed by the Boiler Code Committee (which proposal is concurred in by our Society) to call for the non-destructive test. Thus the processes that have been proven are now provided for by a method which will not call for the expense of non-destructive test. It is not the purpose of the code-making groups to saddle unnecessary expense on a class of vessels that have been proven by experience and use, but the idea is that when we depart into the realm of these thick-walled boiler drums and these high-duty pressure vessels, perhaps it may be desirable to have a non-destructive test and make the sale of the idea of welding on those classes of vessels easier to both the customer and to the inspector and the insurance company authorities.

PRESIDENT DOYLE: Mr. Hodge made the statement, I believe, that the cost of x-raying was fifty cents a linear foot of 1-in. material. I don't know whether I am correct or not in believing that 3 in. is more or less the limit to which x-rays now apply. Does the cost go up in a direct ratio with the thickness?

MR. HODGE: The cost goes up very much faster. For 3½-in. plate, which is the maximum thickness we have x-rayed, the exposure time will be approximately 1 hr. and 10 min. We figure on an operating cost for the x-ray machine and operator of $5 per hour, which is an approximate figure, but from this you can readily see that the cost for 3½-in. thick vessels will be approximately $5 or $6 per foot, but even so this cost is not out of proportion to the total cost of so thick a vessel. A vessel 3½ in. thick x 30 ft. long, 4 ft. diameter, would have approximately 55 ft. of welding. At $6 per foot the cost of x-ray examination would be approximately $330, which is a relatively small item in the total cost of a vessel of these dimensions.

There is only one thing I would like to say in defense of rigid specifications for welded pressure vessels which are to be built in the future as compared with the satisfactory results in operation of welded pressure vessels which have been built in the past to no specifications, but which, nevertheless, have given satisfactory service for some ten years. Take, for example, boiler drums which have been in service for 30 or 35 years, a period three and one-half times as long as the welded vessels which have been in service under less severe operating conditions. There is no reason to think that because a vessel holds up for ten years that it will continue to hold up for 30 years, particularly where the problem of fatigue stresses enters into service conditions of the drum. About two weeks ago we had called to our attention a case of a pressure vessel which had failed under fatigue due to development of fatigue cracks from small defects on the surface of the plate, the failure not occurring in the weld but in the plate material. Regardless of what our opinions are regarding the relative qualities of weld metal, plate material will on the average be superior to weld metal and if failure by fatigue can occur in good average plate material of pressure vessels, failure by fatigue can more readily occur through weld metal. When you consider welding of drums and vessels which will have to withstand severe operating conditions over a large number of years, under which conditions fatigue stresses enter into the problem, we should take every precaution to insure that the quality of the welded joint is as good as the plate material. This can only be secured by a rigid specification, including x-ray examination, and we should not take the satisfactory results of welded pressure vessels over a relatively small period of time as a basis of argument against a rigid yet reasonable set of specifications under which welded pressure vessels may be built in the future.

MR. OWENS: Mr. Chairman and Gentlemen: The physical characteristics of weld metal can be improved by a thermal treatment at temperatures below the critical range. Tests made by me have proven that the ductility of the weld can be increased and others have shown that residual stresses are relieved at temperatures as low as 700 deg. Fahr. In important pressure vessels, it certainly is essential to thermally stress relieve and in many other cases desirable, although not always necessary. Good workmanship and a carefully worked out welding procedure are always essential, but some degree of residual stress will always be present unless the product is thermally stress relieved. In this connection I might say that on many jobs that I have been called in on in my consulting practice, the trouble has been due to such stresses. Neverthless, I can assure you that there is nothing to fear if the problem is understood and properly handled.

Discussion paper† on "Welded Machinery Foundations for Ships," by Mr. G. H. Moore, Newport News Shipbuilding & Drydock Company.

MR. L. C. BIBBER (U. S. Navy Dept.): Mr. Chairman and Gentlemen: I have enjoyed Mr. Moore's paper very much. In his sketches he has shown intermittent welding connecting the longitudinals to the cover plates. I am also inclined to prefer the intermittent welding for such work. We recently had occasion to figure a foundation on one of the small welded craft that we are making and found that the maximum possible stress that could come on the welding, due to a sudden stopping of the ship, as rolling or dead weight, or from any other cause, was but a few thousand pounds, and if I remember correctly they had welding worth some 3,000,000 lb. to hold the foundation together. In other words, they were using continuous welding, and warping their structure all out of shape for no reason whatsoever. That, I think, has been one of our troubles; we have been using too much continuous welding.

The manner of welding around the riveting here is very interesting. That is a problem we have to contend with in shipbuilding a good deal, construction with both riveting and welding.

Mention is made in the paper of a Diesel engine foundation which was riveted and which broke loose in service. The foundation in question was made up of about eight by eight angles, about 1 in. thick, enormous members, and the heavy riveting had been shaken loose by the vibration of the engine. That foundation was welded and as far as is known it has given wholly satisfactory service.

We are very much interested in saving weight in Naval construction. The boiler and machinery foundation is an ideal place to save weight because you eliminate connecting angles which have no function other than connecting members together. When you have eliminated an eight by eight angle or some other large member, used in engine and boiler foundations you have made a great saving.

CHAIRMAN OBERT: Mr. C. W. Bryan, Jr., of the Federal Shipbuilding and Dry Dock Company, Kearny, N. J.

MR. C. W. BRYAN, JR.: Mr. Chairman and Gentlemen: It is a pleasure to indorse a paper from Newport News, a company that has been so courageous in pioneering welded work in shipbuilding and so generous in giving its discoveries to its associates. After reading this paper, it seems strange that welded foundations have not been adopted more widely. Shipbuilders are using machines of welded construction in their shops and the local vibrations and stresses in these tools are greater than in welded foundations. Mr. Moore said that the shipbuilder strives to please the owner. In fact, he must do so, but he has an obligation to advise him also. If the owner does not want welded foundations, the builder can submit that type of design only as an alternate, which means additional expense for the second design. The main obstacle to the wide adoption of this method of fabrication is that during the very period when the principal shipyards placed their welding fabrication under strict control, well within the limits of known reliability and with no necessity for x-ray inspection.

†Paper published in the April, 1931, issue Journal of the A. W. S.

ship designers were proposing a wide variety of new propelling units. The large and heavy Diesels move slowly, the lighter and smaller Diesel engines move more rapidly, and modern turbines rotate at high speeds. These widely different engines have presented new vibration problems and the conservatism that is characteristic in marine design, has delayed changes from the conventional riveted foundation structures. It appears likely that in the very near future the advantages of welding machinery foundations will become evident to all concerned and their use more widespread.

MR. OWENS: Mr. Chairman and Gentlemen: Mr. Moore has very clearly presented the simplicity of the design of welded machinery foundations for ships. In addition he has clearly shown how symbols can be used to simplify a drawing. These symbols are embodied in the Nomenclature report of the Society and have been adopted by the Navy Department.

When one considers the simplicity of welded machinery foundations, it seems strange that they were not the first parts of the ship to be welded. The reason for this is that operating engineers have been reluctant to accept welding on any part in any way connected to the machinery installation, fearing failure under service conditions. However, as is frequently the case, the possibility of lower costs overrides other considerations and makes for progress. As it is not always possible to decide on the pumps and other auxiliaries to be installed prior to the completion of the main structural drawings of a ship, both the drafting room and the shop organization of the Newport News Shipyard saw the possibility of completing these drawings and starting fabrication without waiting for decisions on equipment. In view of this the management took an unusual position and requested that machinery foundations be welded. With this practice in effect, decks and bulkheads can be completely installed and foundations attached at any future time, thus advancing the date of delivery of the ship by not holding up construction. By eliminating the leaks inherent in riveted construction, not only is the cost of testing reduced but time of delivery is also shortened.

Mr. Bibber has brought out a very important point, viz: the advantages of intermittent welding over continuous welding. Tests and experience have shown that thermal stresses are lower for intermittent welding than continuous welding with the result that the problem of warping is very much reduced, particularly where the plate is relatively light. Except for the problem of corrosion, intermittent welding could be used more extensively than it is. Mr. Moore's paper shows how this problem is taken care of and how leaks are avoided when welding is combined with riveting.

Of course, there is a lot yet to be done in the welding of foundations for I have not as yet succeeded in securing completely welded main turbine foundations, although a large amount of steel work could be eliminated and the design materially simplified. Even for this type of foundation, "vibration" as a reason for not welding is not tenable for, as pointed out by Mr. Moore, it has been necessary to reinforce a riveted Deisel engine foundation by means of welding, because this type of construction would not withstand vibration and welded construction would. Another advantage of welded foundations is that they can be readily reinforced should points of vibration be discovered.

MR. F. T. LLEWELLYN (U. S. Steel Corporation): Might I express appreciation of Mr. Moore's paper, and at the same time give a warning of the danger of assuming that facts which are true in one field are necessarily true in other fields. I have in mind the comparison that Mr. Moore makes as to the economic size of fillet welds. Mr. Moore's statement is theoretically correct and in shipbuilding it may be practically correct. In other fields, however, such as structural work, it would not be applicable, for this reason:

You wish to join one plate to another. If they closely abutt, that is to say, if the weld fills the entire space and is in contact with the metal at all surfaces, then the considerations mentioned in the paper apply. But in other lines of work, not shipbuilding, we do not usually get that condition.

There is apt to be clearance between end and surface which will run an eighth or more. Now it is quite evident that while the leg of the fillet may be three-sixteenth, the surface in contact is not three-sixteenths. The throat is no longer a measure of the strength of the weld. The surface in contact is the criterion.

I mention this, not as taking issue with Mr. Moore's statement, but as a warning against the indiscriminate use of ultra small welds, even though they figure economically, in cases where the conditions don't support the assumptions.

A second point is with regard to composite joints in which rivets and welds are both used. I am satisfied that they do not act together; that they are very much like the old-fashioned tandem team that we used to drive with one horse in front of the other. The horse nearer the cart did most of the work.

G. H. MOORE, JR. (Newport News Shipbuilding & Dry Dock Co.): Mr. Chairman, I want to bring out in connection with Mr. Llewellyn's diagram, the point that we often have in ship work the condition of not being able to get metal to metal contact, or faying surfaces together, as we call it. The ideal condition is metal to metal, but in practical work we are not often able to do this regardless of how we try. Therefore we have to increase the weld size to take care of this condition. In other words, if our two pieces are a sixteenth apart, a ¼-in. fillet weld would have to be increased to 5/16. I think that Mr. Bibber showed theoretically that no harm is done, while in practice we have experienced no bad results.

On the Aircraft Carrier "Ranger" we have to take this in consideration because the shell and other parts of the ship are often curved and making a perfect fit is a very mean job. Aligning of the rivet holes allow for some adjustment so we should allow for it in welding.

CHAIRMAN OBERT: We have with us today a visitor from foreign shores whom we are very glad to welcome to our convention. I would like to call upon him, but before doing so I want to call attention to the work that has been done on the other side of the ocean in welding of ships. Perhaps many of you are familiar with the advanced stages of welding construction in shipyards and the interest that our marine constructors are beginning to take in welded construction as a result of what has been accomplished over there.

One of the eminent German engineers interested in this line of work is in this country at the present time. He has been looking over a number of the shipyards in this country and endeavoring to get in touch with

what is going on here. I think he has visited Newport News Shipyard and perhaps some others.

It occurs to me that if he would be willing to stand before us and give us a word as to what is going on in Germany and perhaps tell us a little about what he thinks of the accomplishments we are making in this country it would be very interesting. I would like to introduce Captain Hermann Lottmann, in charge of construction at the Wilhelmshaven Navy Yard, Wilhelmshaven, Germany.

CAPTAIN HERMANN LOTTMAN: Mr Chairman and Gentlemen: I consider it an honor to be asked to attend your meeting. I have listened with great pleasure to these two papers and the remarkable discussions. I may be permitted to make a few general remarks. During the three weeks that I have been in America I have visited a number of shipyards and manufacturing plants specializing in welding with the result that I have seen some very interesting applications by several welding processes both gas and arc. Much of this work was excellent. I am particularly impressed by the good specimens and tests of welded thick material. Of course my experience has been principally in shipyards and the construction of ships. At the Wilhelmshaven Navy Yard we have welded twelve destroyers and three cruisers and the applications of welding increased with each ship constructed. As a matter of fact with the exception of few parts all joints are welded. We have had as many as 100 gas welders and cutters and about 200 arc welders. We have found by actual comparison that the cost of welded ships is about 8 per cent less than riveted ships and that the saving of weight runs on an average from 12 to 17 per cent.

We are entirely satisfied with welding as a method of constructing ships and we will never go back to riveting. Any one who doesn't favor this development is not wanted in our shipyard. I think the development in building merchant ships must go in the same direction.

In conclusion I would like to mention the great courtesy shown me by the Navy Department and by the various concerns visited for which I am very grateful and particularly my cooperator and esteemed friend, Mr. Owens, who arranged with me the route for my trip and gave me many introductions to the different manufacturers. I thank you.

CHAIRMAN OBERT: The Captain was apologizing to me this morning for his inability to use our language, but I want to compliment him on handling it very nicely. I think if we go over to Germany and spend three weeks there and do as well, we will be doing very well.

Is there anybody else who would like to speak on this subject of Mr. Moore's paper before the session closes?

MR. LINCOLN: I want to say one thing in connection with Mr. Moore's paper that is incidental but of considerable interest, I believe. The art of welding at the present time is growing toward metal which is ductile and there is no question that the use of ductile metal in the weld is going to come into much more general use in the near future than it has in the past. Ductile metal is deposited only in the absence of oxygen. Whether it is necessary also to get rid of nitrogen to get rid of brittleness is another question, but you certainly have got to get rid of oxygen.

It is a fact that a good many of you who have used ordinary bare wire welding for parts which are heated and cooled repeatedly have found that an ordinary bare wire weld rots (you can call it that) with repeated heating and cooling. Those of you who have had experience in that sort of work will remember that corner welds are used in making a basket, for annealing laminations. The annealing of the laminations, of course, heats the basket up to a red heat and it is cooled every time that the batch of laminations is treated. Those of you who have had experience with that sort of vessels know that the ordinary barwire weld will after a number of heatings and coolings start to crack through and in a comparatively short time the weld is broken and drops apart.

But if that weld is made with an atmosphere which contains no oxygen these welds will remain in good shape. They will not deteriorate or experience this rotting process which I have spoken of which breaks the weld.

I made some carbon arc welds a good many years ago in which the atmosphere was controlled and these welds were heated and cooled fifty times up to a temperature of some 1500 or 1600 Fahr. and at the end of the time the welds were just as good as they were before the test was started.

Tests show that the same thing is true with reference to corrosion as is true with reference to the resistance to repeated heating and cooling, namely, that a ductile metal has a much better resistance to corrosion than a metal which is not ductile, which is simply another reason for always insisting on the use of ductile metal in all welds.

MR. A. M. CANDY (Westinghouse Electric & Mfg. Co.): By way of introduction, I would like to just amplify the remarks of Mr. Obert relative to Captain Lottman. I had the pleasure of spending a day with Captain Lottman at our East Pittsburgh Works a short time go and he assured me at that time, that although he had studied English in college thirty years ago he had had no occasion to talk English until he came over to the United States on this trip, although he had been reading English in the meantime. I thought it was a wonderful commentary that a man could study English that long ago and merely read it in the meantime and yet speak it as fluently as he did today and the day he was at our factory. It is certainly a real accomplishment.

Relative to Mr. Moore's paper, I saw quite an interesting item (some of you probably have seen it yourselves) in the current issue of *Engineering* of London relative to the ship Fulligar that was welded in 1920. Many of you may remember that vessel so I made just a few notes as to its history up to the present time.

Just to refresh your memory the boat is 150 ft. long and approximately 24 ft. wide and it has a cargo capacity of some 25,000 cu. ft. It was launched in February of 1920, and after being launched was grounded several times and in June, 1924, according to this article it was grounded on the sand, floated and went to Belfast to discharge cargo. They examined it and apparently there was no leakage so they decided to send her on. It was then taken to Liverpool and put in drydock. While in drydock it was examined more carefully and it was found that the entire under plating of the vessel had been raised at least 11 in. over a length of 70 ft. from one keel to the other. That is a real dent in the bottom of the boat, and yet it hadn't sprung any leaks, and at the

time was in such good shape that they decided not to renew anything but simply force the plate material back into position by means of jacks, etc. It was forced back. Some of the framing had to be replaced, and the boat was put in service and showed no distress whatever. It changed hands and went into the hands of the British Columbia Cement Company and the vessel was renamed the Shehan. So if you see any reports referring to the Shehan, it is the old ship Fulligar.

The boat was permitted to go from England across the Atlantic through the Panama Canal and up the Pacific Coast to get into the hands of this British Columbia Cement Company. Last October it hit on a rock off Victoria and crushed the bow of the vessel very severely, as shown by pictures that are in this article. It had on board at the time some 10,000 bags of cement and in the crushing at the front end of the boat no weld failed. All failure was in the plate material itself and they only lost 400 bags of cement out of the 10,000. Those who looked over it agreed that if the boat had been of riveted construction and had hit the rock in the same way the whole cargo would have been a total loss.

That shows what welding will do. Incidentally, this same article mentioned that in the course of eleven years' service there was absolutely no indication that corrosion in the welded joints was any more rapid than the rest of the plate material of the hull itself.

MR. OWENS: It is quite an honor to have my friend and coworker—Captain Lottman—with us today, particularly as welding developments in the German Navy have somewhat of a romantic aspect. The reason for this is that when the Versailles Treaty was signed, the few naval ships that Germany was permitted to build were restricted to 9000 tons and 8-in. guns. Furthermore, she could not obtain the required structural shapes from France. These restrictions actually turned out to be a blessing in disguise for the attention of German naval architects was attracted to welding with the result that they have already built several welded destroyers and three welded cruisers, the latter having a length of approximately 500 ft. By welding instead of riveting these cruisers, it was possible to mount 11-in. guns and obtain other military advantages and yet keep within the requirements of the treaty. Practically the only medium steel part of the hull not welded is the longitudinal seams and welding was not used for these seams because the rivet holes facilitated assembly and erection. The results of this extensive use of welding on naval ships by Germany has not only waked up our own nation but all other nations, and the development is having its effect on both ship construction and the welding industry as a whole.

The welded destroyers referred to by Captain Lottman are longitudinally framed throughout, this construction not being previously possible in the fore and aft sections of a destroyer when of riveted construction. Captain Lottman jokingly referred to the "pocket battleships," but nevertheless, gentlemen, they were able to mount some pretty husky guns on these ships.

In conclusion, I will say that Captain Lottmann's work has closely paralleled my own, and although working independently we have in practically every respect arrived at the same conclusions.

The session adjourned at 1 p. m.

SECOND SESSION
WEDNESDAY AFTERNOON
April 22, 1931

The Second Session convened at 2.15 p. m., Mr. H. M. Priest presiding.

CHAIRMAN PRIEST: We have a fairly full program this afternoon so that I shall make no preliminary remarks. As you all know, structural welding probably had its best year in tonnage during the year. 1930. You may have read in the various periodicals of the 20-story buildings that have been put up in Dallas and in Los Angeles and there have been numerous large industrial buildings erected during this period. So that the subject has become one of increasing importance. This afternoon we have three papers dealing with different phases of structural welding. The first one treats of its practical application to steel structures. The second one will deal with problems of design and the third with tests, which are always useful in the planning of new work.

The first paper on the subject, "Some Examples of Welding in Structural Steel Work," will be presented by Mr. D. C. Tennant of the Dominion Bridge Company.*

(Mr. Tennant presented his paper.)

I am sure you will agree with me that this has been a thought-provoking paper. The extent of the work that has been done and its variety are very inspiring. If it is agreeable to the audience, we will leave the discussions until all three of the papers have been presented, as they are along the same lines.

The second paper this afternoon is, "Formulae for Eccentrically Welded Connections," by Odd Albert, Bridge Designer, New Jersey Highway Commission.†

(Mr. Albert presented his paper.)

The thanks of the Society are due Mr. Albert for his presentation of the paper to us. We are indeed fortunate to have had him with us. Every designer who has to handle eccentric connections will keep this paper close to him.

The next paper on our program is, "Some Tests of Gas Welded Structural Joints," by H. H. Moss, Linde Air Products Company.‡ Mr. Moss needs no introduction to this audience but I present him to you.

(Mr. Moss presented his paper.)

I will now open the meeting for discussion. We have an opportunity this afternoon to acquire a good deal of information from these gentlemen who have presented papers to us and I hope that you will all take full advantage of it by asking them questions.

MR. HENDRICKSON (Philadelphia): Looking over Mr. Tennant's paper and listening to it, I am afraid there are not many remarks to make. He has covered everything very thoroughly. I would just like to ask one question and that is, Mr. Tennant brought up the point on rivets—are there any particular features of welded design where he thinks danger might occur and what we should watch out for more than anything else.

MR. TENNANT: I think the main point you have to watch is that your welders are qualified. After all it depends on the individual man. I don't mean by that that you can't tell good welders or that welding is unreliable, but I do think you are taking a blind chance in going ahead and welding without

*Paper published in the April, 1931, issue Journal of the A. W. S.
†Paper published in the April, 1931, issue Journal of the A. W. S.
‡Paper published in the May, 1931, issue Journal of the A. W. S.

knowing the utmost of the men who are doing the job.

MR. BIBBER: I just had the opportunity to glance over Mr. Albert's fine paper and was very much interested to see that he had touched on a subject that had given us considerable concern. There was one point that I noticed in the derivation of his formula. It is my impression that in a rectangular section the sum of the two equatorial moments of inertia does not equal the polar moment of inertia. That is true only in the case of circular sections. If I remember correctly, the equatorial moment of inertia of a square is BH cubed over 12 and if you added two of them together you will get BH cubed over 6 for the polar moment of inertia, whereas I believe that the polar moment of inertia of a square is two-ninths BH cubed.

That being the case, I wonder what would happen where you have, as we so often do in ship construction, an eccentric bracket connection which departs altogether from a symmetrical section? I know of no way to find the polar moment of inertia of any such section, but to take increment and by main strength and awkwardness figure the empirical or approximate moment of inertia of such a figure. If Mr. Albert has any information on figuring the resistance to torsion of such a connection as that, I would be very glad to know about it.

MR. ALBERT: I must say I have not any information. I would like to think it over.

MR. BIBBER: In ship construction such connections occur and I have no very satisfactory way of figuring it but if Mr. Albert has along that line any information on the method of figuring such a connection we certainly would be glad of the enlightenment.

MR. ALBERT: I think it requires a lot of thought anyway.

MR. LLEWELLYN: I would like to express very great personal appreciation of all three papers. As regards Mr. Tennant's paper, I happen to know that the technical secretary of the Society repeatedly invited Mr. Tennant to give papers in the past and he stated that he was not ready. We know that he was interested in the work but he wanted to wait until he was quite ready. Tennant is to be congratulated on the result of his waiting.

I would like to put a question, however. Mr. Tennant showed us two distinct methods of connecting H sections to a base. In one of them an H section or its equivalent was connected by welding at the four toes, that is at the four extremities of the flanges. In another illustration which he showed, there was no welding at the toes, but there were lines of welding along the edge of the flanges. It may be that those two types were for different purposes, but I would like to know by what rule those two different arrangements of weld are classified.

As to Mr. Albert's paper, he was very modest. He didn't tell us something that we ought to know, and that is that during the past twelve months several papers have appeared under Mr. Albert's signature in *Engineering News Record* in which he has done for riveted connections exactly what he has here done for welded connections. The ease that will be enjoyed by anybody applying his charts is noteworthy.

In listening to Mr. Moss's paper, which I did not have a chance to read before, I gathered this impression: The results of the tests on full size joints disclosed higher unit strength than the results of the tests on specimens. For example, joints one and two showed factors of safety of five and four, whereas the third specimen showed a lower factor of safety.

I raise the question because I rather suspect that reflects exactly what happens. When we carefully design specimens [not joints] for the purpose of getting basic values, we are doing something that is conservative indeed, for when those results are later applied to actual joints, we get results that are usually somewhat better.

I am not sure if I have interpreted the results correctly, but that was the impression I got.

MR. TENNANT: I would like to thank Mr. Llewellyn for the interest he has taken in reading over my paper. Thanks are also due the American Welding Society for being instrumental in putting before all the structural companies useful information in connection with welding; and Mr. Llewellyn, when he was President of the American Welding Society, was as much responsible for that as anyone.

I don't think I can stress too much what all companies owe to this Society. It has been a well conducted, very successful and helpful Society so far as my observations go and I believe it is going to continue to be so.

Regarding Mr. Llewellyn's question, I think I know the examples he is referring to. The weld at the corner of the columns for fastening on base plates was applied to larger columns, ten by ten, fourteen by fourteen, and the only case where a weld was put on in two continuous fillets, one along each flange, was on a very much smaller column. What we had thought of doing with the larger column was to put at least 5 in. of weld in each corner of the column fastening on the base plate. The other case is a five by five column, where it seemed quite sufficient to put 5 in. of weld along each flange.

MR. MOSS: While not being clear as to the question put by Mr. Llewellyn, I believe that he is endeavoring to point out why the factors of safety in these several specimens vary so widely, being 3.13 for Fig. 3, 4.17 for Fig. 2, and 5.35 for Fig. 1.

In the case of the bar splice, Fig. No 3, a unit tensile strength of 18,000 lb. per sq. in. governed the strength of the joint bars and welds were provided to develop the strength at that unit tensile stress, the welds being designed in accordance with the stresses recommended by the American Welding Society's Structural Code which, for shear, is 11,300 lb. per sq. in. on section through the throat of weld.

In determining the dimensions of the welds for Fig. 3, the recommendations of Messrs. Weiskopf and Male as to ratio of end to average stress were followed. The indicated end stress for the condition shown in Fig. 3 was approximately twice the average stress of 11,300 lb. We might expect failure to occur in that joint bar just where it did.

I failed to mention one point that I probably should not have overlooked. Base metal specimens were extracted from these materials and their physical properties determined and aside from the .505 specimens which ran a little high, the rectangular specimens which were extracted gave an ultimate tensile strength of about 57,000 lb. per sq. in. for the bars used, which value is to be compared with over 56,000 lb. per sq. in. developed in the joint bars at the point of failure of the specimen, on the basis of dividing the total load by the gross area of the bars.

I think that there is quite a degree of consistency in the results of the tests of this specimen as the full strength of the joint bars was developed under con-

ditions which might be considered balanced from the standpoint of popular design.

In connection with the other specimens, the factors of safety show more consistency, but, of course, we must remember in these tests the loads were applied a little differently than they might be applied in an actual building, the condition for which they were presumably designed for.

In the case of Fig. 1 in a building, the beam would bend and it might be expected that under such conditions the bracket strength might be reduced somewhat. My own office has, however, adopted a factor of safety of five for this purpose unless fixity is assured by some other means.

As to Fig. 2, failure occurred by detail crippling in the compression flange, a typical failure for a specimen of that type. Had the top bar been reduced to a minimum under the assumptions of design, I am sure that the same results would have obtained. Beforehand, I had thought that some lateral condition might develop which would determine failure, but none developed. Both flanges acted as true cords and the indications of yield point stress in the web were typical for that type of loading.

These tests were not conducted in a manner to obtain the maximum data. It would have been interesting to have an opportunity to apply strain gages on parts of these specimens to obtain more data as to stress distribution, but that wasn't possible. All of these tests were conducted in a very short time precluding the possibility of thorough detailed observation. However, the results would seem to be rather consistent after we think about the function of the three details and compare the results with the design assumptions.

MR. LLEWELLYN: In general, yes, Mr. Moss. After reading the paper (I hope it will be published), one can perhaps discuss it more intelligently.

MR. CANDY: I have just one suggestion that I might raise. Mr. Tennant's paper certainly covers a great deal of ground and is very interesting reading. There is just one detail that has been suggested by some people recently and that is the question of built-up trusses and girders, such as Mr. Tennant has shown. Taking the panel angles and instead of putting them on in the conventional way with one leg in contact with the cord member and the other leg extending outward in that manner, turning the angle in an unconventional position with both toes against the cord stem and welding it on in this position, along the toe edges. The question of appearance of the structure, and the fact that both legs are attached to the member makes it look as though one might possibly make a better attachment. I wondered if Mr. Tennant has given this any thought or study.

CHAIRMAN PRIEST: That same detail of welding both edges of the angle (I think I am correct in saying) I first saw in one of Mr. Lincoln's bulletins that his company put out and I wonder if he, perhaps, can tell us how that detail has worked.

MR. LINCOLN: I am sorry to say that I can't answer the particular question that you have raised. The impression that I get from the discussion this afternoon is a general one. I have been a member of the Welding Society for a good many years and maybe eight or ten years ago the Welding Society meetings were very much smaller than they are now, only a handful at that time, and the discussions which occurred at that time were completely different from the discussion and the papers we have had this afternoon. The papers we have had this afternoon are high grade technical papers, the same sort of papers that you will get if you go to the American Institute of Electrical Engineers' meeting. The kind of papers and the sort of discussion which occurred ten years ago were very amateurish as compared with what we have had this afternoon.

The questions, then, you know, were whether you could weld at all or not and there was a good deal of a fight on between the electric people and the gas people as to whether either of them were going to make any welds at all. Each was complaining that the other was no good and all that sort of thing. The contrast between the discussions and papers that you have had this afternoon and (you could hardly dignify them by the name of papers), the presentations and discussions which occurred ten years ago are to my mind a very interesting comment on the growth in usefulness of the American Welding Society.

MR. SCOTT: Mr. D. C. Tennant stated that the weld shown in Fig. 22 along the I-beam was performed in the shop and the weld on the truss was done in the field. I was wondering whether he gave a thought to doing away with this doubled plate and inserting the gusset or stiffening plate against the girder itself. Is there any particular reason why that could not be done on bridge work as we are doing it on regular ship construction?

CHAIRMAN PRIEST: There is one thing that struck me about Mr. Tennant's paper that I might call attention to and that is his connections for beams to beams, in which he has used the detail of two connection angles to connect the web. I think that connection is a very commendable one. He has made allowance for the bending that you would get on such a connection when the beam begins to deflect under its load. The welding of the web directly to the girder would be a rather dangerous thing to do, from a strength standpoint, but, as he has it arranged, the angles can bend slightly and relieve that stress which would otherwise come directly on the weld itself.

Another point that interested me in Mr. Tennant's paper was the fact that they have a committee working on standards for the structural joints. I am rather inclined to agree with him that it is somewhat early to attempt to standardize the connections in the same way that we have in all the structural handbooks for riveted work. But undoubtedly the time will come when the connection of such beams to girders, seat angles, etc., will be worked out in some standardized form.

I should like to ask Mr. Tennant if they exceed $\frac{3}{8}$ in. weld in much of their work. Do you go to $\frac{1}{2}$ in. and $\frac{5}{8}$ welds or try to arrange details to use $\frac{3}{8}$?

MR. TENNANT: We don't exceed $\frac{3}{8}$-in. weld in much of our straight structural work. We do sometimes use larger fillets, but we always give them special consideration. Mr. Cape, our shop welding engineer, is here this afternoon and he knows more about what we do in connection with actual shop welding than I do. Perhaps he might say how often we exceed $\frac{3}{8}$ welds.

MR. G. CAPE (Dominion Bridge Co.): There is some welding over $\frac{3}{8}$, but the majority is 5/16. Up to $\frac{3}{8}$ we find it better in single layer and above that it is made in two layers.

CHAIRMAN PRIEST: We are greatly indebted to the three speakers who have come to us this afternoon and given us the benefit of their experience on this subject. I hope that you will give these papers

some quiet study when you get back to your offices or to your homes. If there are no more questions I will declare the meeting adjourned.

(The meeting adjourned at 4.45 p. m.)

THURSDAY MORNING

April 23, 1931

Discussion paper on "Some Resistance Welding Problems," by C. L. Pfeiffer, Western Electric Company.†

PRESIDENT DOYLE: Gentlemen, you have heard Mr. Pfeiffer's very interesting paper on resistance welding, which is a subject we have had quite some difficulty in having presented to us from time to time. You also probably heard him say in the beginning that it was elementary. Possibly to those of you who are in the resistance welding business it is. I venture to say that to the average of us it is very far from elementary.

MR. H. A. WOOFTER: Mr. Chairman and Gentlemen: I regret these other gentlemen are not here to discuss this paper which I think was a very, very good one. I always have maintained and still maintain that the users of the resistance welding machines. such as the Western Electric Company, are in a far better position to give good interesting papers than the manufacturers of such apparatus, and for this reason: the users of the apparatus are making millions and millions of welds in ferrous and non-ferrous metals, one after the other, and they learn many, many things which the welder manufacturer doesn't know. He has built a machine and makes perhaps a half dozen welds to test his machine. He then turns his attention to the next welder which may be for a job of an entirely different character.

I think Mr. Pfeiffer's paper is very timely for a great many reasons. Referring to his Fig. No. 2 in the lower part, there is some correspondence now on my desk at home which I have not had time to act upon asking for information about that very same thing. What I will do will be simply to refer the inquirer to Mr. Pfeiffer's paper and he will be properly enlightened.

Another interesting thing in connection with Mr. Pfeiffer's paper is that he has got off the beaten track and has given us some insight into especially the non-ferrous uses of resistance welding. Most anybody can come in and talk about the welding of iron and steel, because that is done in thousands of plants all over the country and is taken as a matter of course, and nobody pays any attention to it any more. It is interesting to consider, however, some of the little machines which he showed in his illustrations weighing perhaps 5 lb., and it is a question of almost jumping from the sublime to the ridiculous.

That is, the standard arc or gas welding apparatus will weigh about the same number of pounds for practically any use you want to put it to. You can get a little resistance welder on which you weld the wires of radio tubes and from that up to welding 10-in. diameter steel shafting. So you can see the enormous range that is covered by resistance welding. I take it, however, that Mr. Pfeiffer does not have many of the larger type of machines in the Western Electric plant.

In 1919 a 500 KVA resistance welder was built which at that time was the largest resistance welder that had ever been built in the United States. Perhaps some larger one might have been built in Europe of which we did not know. Now, a 500 KVA welder is a mere infant since we have been making them in as large as 6500 KVA units.

It is fortunate that we have large manufacturing concerns who are willing to contribute papers of this nature for the reason that most of such concerns have large laboratories in which they can do experimenting and perhaps have a corps of analysts and chemists and physical research men. Whereas the ordinary manufacturer of welding machines cannot afford to carry those things out. It is his business to build the welding machines and he knows they will work, but for the great majority of uses they may be put to, he cannot investigate them all; he hasn't the time to do it.

I would like to suggest something. I wish that some of our biggest users of resistance welders, such as the General Electric Company, Westinghouse Company, Western Electric, all of the automobile concerns, the pipe manufacturers, etc., would get together and do some experimenting about along the following lines. You all know, of course, that what is known as projection welding or by some called embossing welding has been coming to the front very strongly in the last two or three years, but there is very little actually known about many things in connection with it, and here are some of the factors that are unknown and should be investigated:

On thin metals how far can we go down making projections and then making projection welds properly? What is the relation of the height of the projection on very thin sheets to its thickness? What is the maximum thickness of stock that can be embossed with projections so as to make projection welds? What is the relative height of the projection or what is the ratio of the projection to the thickness of stock? How close together can or should the projections be placed? What current values or what ratio of current values should be used as regards the number of projections? Would ten projections require ten times as much current as one? What is the maximum number of projections that could be made on a resistance welder at the present time? The greatest number I know of is 24, but I have heard rumors of 40 projections being welded at once. However, it has only been a few years since it was thought that six or eight was the maximum number that could be made at one stroke of the punch press type of resistance welder. Can projection welding by the resistance process be successfully employed to join together thin sheets of copper? I have had several inquiries regarding this during the last year but have had no equipment on which to try it out or make such tests. I hope Mr. Pfeiffer can help us out in the future on that. We do know that a height of projection of about .055 in some cases gives magnificent joining of plates that will be stronger than riveting. We know of other cases where ten such projections of such height are not as strong as five projections with two or three times greater diameter and two or three times greater height. There must be some definite relation or ratio that could and should be worked out and which would enlighten us all, the welder manufacturer as well as the user.

I was very glad that Mr. Pfeiffer brought out another point, namely, making welds under a shield such as carbon tetrachloride. I had never used that par-

†Paper published in the April, 1931, issue Journal of the A.W.S.

ticular liquid but have made welds under salt water and found that in some cases the salt water will act as a catalyzer and that we got much stronger spots than if those same spots had been made in the open air. I had experimented on a few other liquids. However, I never had the equipment to analyze them as a catalyzer. But the best results I got were attributed to the exclusion of the oxygen, but this may have been only partly true. There may have been other catalyzing effects which I was not able and had no equipment to determine.

I question whether many of you realize, although I hope the recent paper has given you just a little inkling, how enormously the use of resistance welding is in present industry all over the country. I wonder if you realize that the head of the needle containing the eye is welded on by many manufacturers. I didn't know it was myself until a few years ago. I have seen a magnifying glass installed so the operator could see when the work was properly lined up, as for instance, in the welding of wires for radio tubes. But I hope that such papers as these will bring out to many of you the enormous uses of resistance welding. Also, it would be hard for us to realize, those who are not in the actual industry, how the industry is going into bigger and bigger units all the time. That was brought out a few moments ago when I said that ten years ago a 500 kva welder was the biggest we had in this country. Now we have them up to 6500 kva.

I regret the other gentlemen who were to speak on this paper are not present, but I would like to say that we are honored by having a distinguished resistance welding engineer here who has had a wide experience in this country in connection with the General Motors interests, as well as a wide experience in Germany and other countries. This gentleman is a very friendly enemy of mine and I believe I will have the approval of our president if I ask him to call upon Mr. Fassler of the Fisher Body and General Motors Corporation here with us today from our city of Detroit. I believe he will be able to make some interesting remarks or discussions on this paper.

P. W. FASSLER (Fisher Body Corp.): Thank you, Mr. Woofter, for introducing me to this meeting.

Gentlemen, I am very glad to have this opportunity of answering a few questions for Mr. Woofter, but I am sorry that I will have to disappoint you somewhat as my English is not so very smooth and, with regard to experimentations in relief or projection welding I will not be able to give you positive facts.

The relief welding process, as we called it in Europe twenty years ago and which has gained so much popularity in this country during the last five years, deserves plenty of hard study and lots of research and experimental work is necessary to enable us to write down certain theories and facts.

We have built and placed into production hundreds of machines of this type on which material of 20 gage up to and inclusive of 5/16 of an inch is welded together by means of five to fifty embossments of varied sizes in one stroke. These machines have been satisfactory and successful, but we have had to work out each particular job individually which, as I have tried to explain to you, is not what we want.

The welding machine industry ought to be able to work out a certain standardization or, in other words, bring together a formula or a relationship between the number of spots or embossments to be welded, the thickness of the material, the size of the embossments, the welding time and the proper current.

This seems rather hard as the welding parts have different shapes and forms which are either an advantage or disadvantage to current travel.

The latest experience we have had with a machine making fifty spots in one stroke on 18 to 20 gage material shows us some very interesting pictures. It is through improper timing and adjustments that we have been using between 20 to 30 kw. per spot but, however, in studying over this proposition we have now devised a way to cut down the power demand to 5 kw. per spot and, at the same time, obtain a much better and more dependable weld. In order to do so we had to study the welding time very closely and especially the operating cam which has to be designed very carefully.

My opinion is that with this method we should increase the welding time which would automatically cut down the amperage or power requirement. Also, the pressure conditions have to be watched very closely, especially with reference to thin stock. By doing so we can build smaller machines and obtain a better power factor in the plants. We welding machine users are particularly interested in keeping the power factor as high as possible.

We used to have the idea that the best relief or projection welding machines were the motor driven type, but I think that now we will have to change this viewpoint as our latest experiences show that an air operated machine has many advantages providing it is equipped with a proper switch with timing element.

I am very sorry that I am not able to give you any more information, but as I have told you before we are in the midst of considerable research work but, possibly, by the time of our next meeting we will have some positive statements to make.

PRESIDENT DOYLE: I want to assure you, sir, we would be very glad to have you write something for us. In fact, if you would be willing to write something along the lines of what you were just telling us and allow it to be published as discussion of Mr. Pfeiffer's paper, we would appreciate it.

Is there anyone else who would like to discuss this paper? The time is getting short.

MR. R. E. WAGNER (General Electric Company): At the Pittsfield Works of the General Electric Company, we use the resistance line welding process in the fabrication of small transformer tanks. These tanks are approximately 30 in. in diameter, 45 in. high and made from steel sheets 1/16 in. and 3/32 in. thick. We do about 2½ miles of line welding each week under normal conditions.

In the development of the line welding process, there were certain problems to be solved and among these was the preparation of the surfaces for welding. Mr. Pfeiffer, in his paper, makes no comment on this phase of the operation. Possibly only clean parts were encountered in his work.

In order to obtain a uniform result, it is not only necessary to adjust the pressure, the current and the time to the proper amounts, but it is also necessary that the surfaces of the parts in contact fit one another intimately and that they be clean and free from scale. Therefore the steel sheets from which the tanks are formed are steel-grit blasted in order that they may have a good clean contact surface. We have had very good success in welding these tanks as the joints are strong and the oil leaks obtained are very few.

We are doing some spot welding of steel plates, two pieces, each ½ in. thick. Here it is necessary to have the surfaces clean and well fitting.

Very little spot welding of ½-in. thick steel is done commercially. We have had a very satisfactory experience in this field with it. The welding of two pieces of steel of this thickness requires a current of about 40,000 amperes, a mechanical pressure of 20,000 lb., on ⅞-in. copper electrodes and an application period of 7 seconds to produce the desired result.

In some of our experimental work we have found that it takes a long time to determine just what the best adjustments are for the best welding results. I recall one problem we had in welding a piece of copper which was in the form of a circle, 40 mils thick and about 5/16 in. wide. The ring was put into the jaws of a butt welder and various adjustments of current, pressure, etc., were made to determine what was required to give a satisfactory weld. One would expect that a fairly low current would be required to weld copper of that thickness. We found that the lower currents would not bring the abutting ends to a fusing temperature at the right time. The copper would get hot on either side of the joint and would buckle under the heat before fusion took place. So that with a low current it was difficult and apparently impossible to make a welded joint.

We found, however, that by applying 25,000 amperes to the circuit for a small fraction of a second, a very excellent joint was made with only a slight burr and practically no indication of heat on either side of the joint.

These experiences are examples of what one might encounter in dealing with welding problems. One will find that the first adjustments are not proper, but after careful trials of pressure, time and current, he will usually find the solution of his problem.

Discussion paper on "The Effect of Welding Procedure on Shrinkage Strains in Butt Welded Joints,"† by Mr. C. H. Jennings of the Westinghouse Electric & Manaufacturing Company.

MR. L. C. BIBBER: I was very much interested in Mr. Jennings' paper and pleased to see that they are working on residual stresses which give us so much trouble in plate work. Some of the results of Mr. Jennings were a little bit surprising to me in that his last chart showing the stresses indicated the values at the end were less than those in the middle. From the results of work done by Mr. Owens I would have expected the opposite. That is, I would have expected the stress at the end to have been greater than those at the middle.

It seemed to me that the specimens with which Mr. Jennings worked were a little bit small and I would like to suggest if this work can be continued with larger specimens, plates 6 ft. wide and 10 ft. long or something on that order, that the results would be very interesting.

As I said before, the work that Mr. Owens has done indicated reversals of stresses and various conditions depending on whether the step-back sequence was used and whether the semi-rigid type of weld was used and various other factors which, of course, have not been brought into account on such a small specimen.

I think that we could all benefit very much if these experiments could be carried further with bigger specimens.

†Paper published in the April, 1931, issue Journal of the A. W. S.

MR. A. M. CANDY (Westinghouse Elec. & Mfg. Co.):

Mr. Jennings undoubtedly has covered the subject in a very thorough manner. For years in our design work at East Pittsburgh the question of residual strains and the design of our joints and the exact welding procedure used has always come up and some of us had one pet idea that if you weld with a certain order you will have but very little strain, if any, and others thought another method of laying the metal down would be better. Up to the time Mr. Jennings did his preliminary work we had no real quantitative data as to just what was the best method to pursue.

In regard to Fig. 4, Type 6, if I understand Mr. Jennings correctly, I believe that each of the central beads was peened immediately after being laid and prior to completing the rest of the beads up the vertical face. It is quite interesting to note that this method apparently produces the best result and gives less residual strain, because it undoubtedly cuts the cost of peening very materially over having to peen an entire layer as you go along, and those of us who have had experience with the shop, watching shop costs, know you don't get your peening done for nothing. As a matter of fact, it runs into quite an item on some of our work.

It also struck me that possibly on this some other data should be included. To merely say that a joint was peened is certainly very far from being quantitative. I think that investigations could be made very effectively going into the factors that actually affect the peening such as the weight of the hammer being used, the foot pounds or inch ounces or whatever it might be that are put into the hammer, the size and shape of the face of the tool that strikes the weld metal, the particular surface that is used on the peening tool, the number of blows per minute, or number of blows per unit of area, and possibly other factors that I don't think of, at present.

In other words, unless we have some of that information, I don't believe it is going to help the other fellow a great deal who decides he is going to peen, except as he cuts and tries and finds out for himself about what gives the best result.

I am a little bit sorry and I realize that everything can't be done in one investigation, but I think it would be interesting (and possibly Mr. Jennings did do it), namely, have a sample peened involving the cross-weave procedure as shown by type one in Fig. II. The reason that I am making that suggestion is this: A number of years ago when Mr. Eschholz, whom many of you know, made quite an extensive investigation of weld metal, particularly involving the direction of laying the weld metal, it was his determination at that time at least that the samples cut from pads of weld metal built up entirely of welding wire gave the greatest strength when the stress was along the lines of the beads which would be the case in type one, Fig. II, stressing the specimen along its major axis.

The next strongest result was obtained where the beads were laid crosswise of the specimen which would correspond to type five of Fig. IV, again being stressed along the major axis of the specimen.

The weakest results of all were obtained where the weld metal was stressed at right angles to the layers. In other words, he built up layer on layer on a block and cut out a specimen with its major axis vertical through that block. That gave the weakest

result. If those facts still hold, it might be that a specimen as type 1 in Fig. II, peened, might prove to be the most desirable of all.

PRESIDENT DOYLE: We would now like to hear from Mr. F. T. Llewellyn, our Past President and representing the U. S. Steel Corporation.

MR. F. T. LLEWELLYN: On agreeing to discuss this paper I had rather expected that it might be more along the lines of the original title, namely strength of joints. I don't feel very well qualified to discuss the paper in detail from any other standpoint. I have observed, however, that for some time there has been a most valuable series of reports issued from the laboratory with which Mr. Jennings is connected, many of which he has had a hand in, and I would congratulate him and his associates on the work they are doing.

The subject refers to the question of residual stresses in fixed joints. In work I am connected with, I recall some advice that was given years ago by the London comic paper *Punch*. It was announced that anybody expecting to marry could secure free advice on the subject if they sent a stamped and addressed envelope to the publisher. Those who did so received an answer consisting of one word—"Don't."

In those fields that I am more familiar with, we aim to avoid anything in the nature of fixity of the joint and are generally able to do so, but we appreciate that there are other fields in which some fixity cannot be avoided. In such cases at first blush one might be a little bit alarmed at one of the conclusions of Mr. Jennings' paper, namely, that in all of the specimens except No. 6 the residual stress near the weld exceeded the yield point. We are accustomed to assume that where a change of length of one thousandth of an inch occurs, it represents approximately 30,000 lb., which is pretty close to the yield point, and, as I recall it, it was only in No. 6 that the results were below that.

That is not, however, to my mind as alarming as it seems, because we get it everywhere. The rules under which we prepare designs are not scientifically correct. They are conventions that have been found to work out satisfactorily within the limits that usually confront us, but I can name a number of cases where there are highly localized stresses way above those that are assumed in design.

Consider a railroad train. The point of contact between the wheel and the rail is about as large as a dime and if you compute the amount of stress at the middle of that area by the usual methods it amounts to about 200,000 lb. per square inch; but your rail doesn't fail there. It is seldom that the rail fails at all, but in those cases where a rail does fail the failure starts from the middle of the rail and progresses outward. In a word, the assumed limits do not govern in this case.

Again, take a riveted joint and cut it open after the joint has been stressed. In many cases you will find that the cross section of the rivet looks more like a crankshaft than a cylinder. There has been visible plastic displacement of the metal. That doesn't mean that the riveted joint isn't good. It simply means that our methods of computation have been generalized, have been conventionalized along lines that have been found to work all right within certain limits.

So, to my mind, in this application of welding to fixed joints, the important thing is to determine within what limits our usual methods of computation apply, and not whether there is a highly localized stress of over 30,000 lb. here or there. That doesn't matter provided the joint as a whole meets the requirements. I think that the tests and experiments which Mr. Jennings has reported are very valuable in leading to this practical conclusion.

MR. OWENS: Mr. Chairman and Gentlemen: I am very pleased to see this paper of Mr. Jennings presented because I have always maintained that a proper understanding of residual stresses is essential for a sound development of welding. It was the first problem I had to face when entering the welding field and immediately conducted a research on the subject extending over a period of three years in order to secure the fundamental information necessary to proceed to design and supervise welded structures. Indeed without this knowledge I would have been groping in the dark and would have had repeated failures which would have prevented me from convincing the Navy Department and others with whom I was associated that welding was a safe method of construction. Without going into a lengthy analysis of the problem it might be mentioned that the research referred to made it possible for me to classify welded joints into four types on the basis of their relative fixity or their inherent characteristics to relieve or retain the thermal stresses produced by welding. This classification is the non-rigid, semi-rigid, rigid and fixed. The non-rigid joint has the lowest residual stresses, and practically all joints in which fillet welds are used fall in this class. This is fortunate for such joints are used almost exclusively in structural work. The other joints are in general butt joints. The joint used by Mr. Jennings in his experiments is that of the fixed type, although not having the extreme fixity which it would have had if the slots were not provided at the ends of the joint.

The research referred to convinced me that fixity is also dependent upon the ductility of the base and weld metals. In other words, the more ductile these metals the lower residual stress. Again, there are only two practical methods of relieving residual stress, viz: mechanical (peening) and thermal (post-heating, usually termed stress relieving).

In the limited analysis undertaken by Mr. Jennings, it was, of course, possible for him to consider only a few of the variables. For instance, he has not considered the deposition of the metal in layers entirely transverse to the joint, a procedure which is desirable, if not necessary, where the weld metal is very fluid. Again, he has not considered the use of covered electrodes, gas welding, automatic welding, etc. Furthermore, he has only considered transverse contraction, whereas longitudinal contraction is just as important.

The curves obtained by me from welds made in the rigid and fixed types of joint in ½-in. plate and joints 4 ft. long and less, all had the characteristic curvature obtained by Mr. Jennings, thus indicating that the stresses were highest in the center of the joint. I found it necessary in my analysis to go one step further than Mr. Jennings by depositing the weld metal in increments of 1 in.

The relative values for residual stress obtained by Mr. Jennings are what one should expect for the deposition sequences and procedure employed. Apart from peening, the reason that the lowest residual stress was obtained in his joint No. VI is that transverse contraction was readily relieved by a thinning down of the plate section as the majority of the beads were deposited on the surfaces of the joint. This deposition sequence is in general not practical.

Relative to peening, if one will refer to page 262 of my book "Fundamentals of Welding," it will be noted that I state that "residual stresses are equalized by its use"; furthermore, that "the section and not the layer should be hammered (peened), hammering being done immediately after completion of the section." By "section" I mean a portion of the entire layer regardless of whether the section be a narrow bead or a bead extending entirely transverse to the joint. In the experiment referred to, the sections were 3 in. long, relatively thin and were the full width of the joint. About two years ago, and when associated with the Newport News Shipyard, I again conducted some tests on residual stresses. In this case the weld was a single V, 8 in. long, and in plates 1 in. thick and 3 ft. square. Two-inch readings were taken across the joint and 8-in. readings over the length of the joint. In these tests I found that peening, while reducing contraction transverse to the joint, actually caused an elongation of the weld and thus compression in the base metal at the ends of the joint.

Basically, one cannot apply heat to metal without producing stresses. Merely heating a spot locally with a gas torch causes the metal to expand and being unable to expand due to the surrounding cold metal, it is compressed, thus causing a tension stress in the area heated and in the surrounding metal. This is exactly what happens in welding, but additional stresses are produced by the contraction of the molten weld metal when filler metal is used to make the weld.

Two other investigators have done some work along this line, viz: Captain Hermann Lottman of the German Navy, whom you heard speak yesterday, and Professor Crook of the Catholic University in Washington. Professor Crook's investigation has been published in the A. W. S. report of the Rail Joint Committee. In the March, 1930, issue of "Marine Engineering," I correlated the tests made by Captain Lottman with some of my own and the results checked very closely.

Due to the importance of this subject, I have suggested to Mr. Spraragen that he arrange for a symposium on the subject.

In conclusion, Mr. Jennings has given us some additional information on the subject of residual stresses in welded joints, the most important being a verification of the fact that there is, even with the most careful deposition sequence and peening procedure employed, some residual stress in the joint. This indicates that, on their important work, thermal stress relieving should also be employed to completely relieve these stresses.

I could go on discussing the subjects for the remainder of the day, but feel that enough has been said by me to impress you with its importance.

MR. LINCOLN: I want to call attention to something which is even more fundamental in connection with residual strains than has been mentioned this morning. The fundamental fact is that melted steel has a volume of 1.07 where cold steel has a volume of one. That being the case, the stretching of metal which must occur between the melted state and the cold state is roughly 2 per cent, the cube root of seven. I understand that 2 per cent is not exactly the cube root of 7, but for the sake of argument we will say that 2 per cent is the cube root of 7. Mr. Llewellyn called attention to the fact that steel has an elastic limit of about one part in 1000. That is one-tenth of 1 per cent. That is represented by the figure 0.001. When steel is stretched to its elastic limit, that is about as far as it will go. The actual stretching which occurs between the melted state and the cold state is represented by the figure 0.020, something like twenty times as much as the steel can stand without distortion. Therefore, whenever you do metallic arc welding you must necessarily have a stretching of the metal which is about twenty times as great as the metal will stand without distortion.

Many years ago I was interested commercially in the welding of steel rails, and if any one of you has ever tried to analyze the distribution of stress in a steel rail welded at the top and bottom of the joint bar, you have got up against a real problem. I concluded that it was impossible to analyze the distribution of stress in such a rail.

Some of the speakers this morning have shown how difficult it is to analyze the stresses in any welded joint. Peening, for instance, will produce an average distribution of stress and relieve the stress on the average. Consider a piece of steel that is peened; whether the hammer is round or flat it is evident that the metal is compressed at one point and only at one point. So that what we have as a result is some of the metal being compressed while the rest of it is still under a state of tension. So that peening doesn't relieve the stresses throughout the mass; it simply averages them up.

However, that brings us back to this point: As it is a fact that we must necessarily have stretching in the metal which is of the order of twenty times the amount of stretching which the metal can stand without distortion, we must have a metal which is ductile and will stand stretching without breaking.

If you use a carbon arc carelessly, you get a crater full of hair cracks. This metal has been melted and there is enough carbon in it so that the metal instead of stretching when it cools cracks when it cools. Any of you who have had much experience have had many experiences of that sort where the cooling of the metal has cracked the metal instead of stretching it. The metal must necessarily be ductile enough so that it will stretch and not crack. If you start these hair cracks in the crater, your structure is absolutely no good.

Therefore, it seems to me the whole question that has been discussed this morning is one of demonstrating the absolute necessity of ductility in the weld metal, and if ductility is absolutely necessary to produce a weld that will cool without cracking you can see that ductility is of great value in the application of weld metal to any structure, and if the metal is sufficiently ductile it will stretch and all internal stresses are relieved. This is simply a way of saying that the introduction of a weld metal which has a ductility of 15 or 20 per cent seems to me a very great step in advance.

MR. G. H. MOORE (Welding Office, Production Dept.): It is information of this character that is most useful in the advancement of welding. Type V is the procedure commonly used at Newport News Shipbuilding & Dry Dock Company, our range of welding being wide as we build hydraulic machinery in addition to ships, and the selling of welding to our customers is an important phase of welding development. Research work of an authoritative character, such as this, is very useful in convincing the inspectors and engineers representing the owners.

Type V is more practical and, I believe, safer in

the hands of an average welder than type VI, although it shows slightly higher residual stress. It is also suitable for both bare and covered electrodes, slag being easily removed and peening facilitated. A check of this kind on established practice is worth while. Mr. Jennings used bare electrodes. Would the results be greatly changed if the deposited metal were more ductile?

In a large structure the question of both transverse and longitudinal permanent shrinkage is very important. Ships might be compared with buildings, in that the ship is a dynamic structure and buildings, static. It is important to know the effect of permanent shrinkage in order that assembly and welding procedures can be worked out with the certainty that no great residual stresses will be left in the structure. At Newport News Ship this problem has been studied in a quantitative manner, but qualitative data is increasingly necessary. It is hoped that Mr. Jennings' future work will elaborate on this important phase of welding and so enable us to better predict results.

C. H. Jennings (Westinghouse Electric & Manufacturing Co.): Referring to the point mentioned by Mr. L. C. Bibber, it should be borne in mind that Mr. Owens's residual stress tests were made on specimens with free ends. If two free ended plates are welded together with a butt weld two types of movement or distortion will be obtained. First, both plates will close together because of the shrinkage of the deposited metal and second, a local shrinkage at the weld will occur from the progressive deposition of the weld metal. This local shrinkage will cause tension in the weld at the outer edges of the plates (points where the weld was started and ended) and compression in the weld at the center of the plate. If the ends of the weld are in tension the fused edges of the plates have retracted a small amount. For the center of the plate, where the weld is in compression, the reverse is true.

If now we consider the results obtained by welding a specimen with fixed ends (this is the type of specimen used in the author's investigation) it is seen that the plates are not free to close together as in the first condition mentioned above, and consequently a high tension stress is produced in the welded plates. The local movements of the fused edges of the plates, however, will be the same in this case as in a free ended case. The retraction of the plates at their edges will tend to reduce the total strain at the edges of the plates while the contraction at the center of plates will tend to increase the total strain at the center point. The result is a higher stress in the center of the plates than at the outer edges. This is the stress condition that was obtained in the writer's tests.

Mr. A. M. Candy's suggestions regarding making tests with more accurately controlled methods of peening are very good. It must be remembered, however, that the tests reported by the writer are only a small portion of the work that should be done along this line, and that in the future additional tests of the types mentioned can be carried out.

The writer is in agreement with Mr. F. T. Llewellyn in that the high stresses which were obtained in the investigation should not be alarming. The value of stress obtained in any welded joint depends upon the rigidity of the joint. The joint used in the writer's investigation was very rigid; consequently the high stresses. The stresses obtained could have been greatly reduced by using specimens with longer slots.

Mr. J. C. Lincoln has given some figures showing the decrease in the volume of metal as it cools from the molten state to ordinary temperature and compared this contraction to the amount of contraction allowable to produce a stress in the parent metal equal to its yield point. It is undoubtedly true that the shrinkage of the cooling weld metal is sufficient to produce very high local stresses adjacent to the weld, but the condition is not as severe as Mr. Lincoln has presented it.

Steel contracts approximately 5 per cent in volume when cooling from the molten to the solid state. An additional volume change of approximately 1 per cent occurs when cooling to a yellow heat and another 1 per cent change occurs when cooling from a yellow heat to ordinary temperatures.* Steels will not take a stress until they have cooled well below a yellow heat. Therefore, the amount of contraction that is responsible in producing welding stress is the result of a volume change of about 1 per cent and not 7 per cent.

In answer to Mr. G. H. Moore's question, it is the writer's opinion that if the welding in the tests had been done with a more ductile electrode, the results would be in the same direction, but there would not be as large a difference between the different welding procedures.

*The Cause and Prevention of Heat Cracks in Aircraft Welding, by H. S. George. Presented before Fifth National Aeronautic Meeting, in Baltimore, Md., 1931.

FRIDAY MORNING SESSION

April 24, 1931

The Fifth Session convened at 10.15 a. m., Mr. A. G. Oehler presiding.

CHAIRMAN OEHLER: The meeting will please come to order. The first paper will be "Thermit Welding in Maintenance in the Steel Mill,"* by Mr. J. B. Tinnon.

I think it probably best that we hold all of our discussion to the conclusion of the final paper. The title of the next paper is, "Metal Arc Welding of Copper Alloys."† It has been written and will be presented by Mr. Ira T. Hook of the American Brass Company.

(Paper read by Mr. Hook.)

Mr. Hook has told you in the course of the presentation of his paper various ways of obviating the difficulties caused by oxygen where it isn't wanted. I have an idea that our next speaker is going to give us some more information along that same line. The title is, "High Tensile Atomic Hydrogen Arc Welds in Alloy Steels."* It was to have been presented by Frederick Ray, Consulting Engineer of the Croll-Reynolds Engineering Company. Instead Mr. S. W. Croll of the Croll-Reynolds Engineering Company will present the paper.

(Paper read by Mr. Croll.)

The meeting is now open for general discussion of any one of the three papers. I appreciate that there is a natural shyness among all men of any considerable ability.

MR. S. S. SCOTT (U. S. Navy Yard): It is with a great deal of interest that we listen to the papers which have just been read before this society, due to the fact that as welding engineers we can visualize that there is a special purpose for each different phase of fusion welding. This morning we had a

*Paper published in May, 1931, issue, Journal of the A.W.S.
†Paper published in April, 1931, issue, Journal of the A.W.S.

paper on thermit welding by Mr. J. H. Deppeler, and then a lecture on the next paper, "The Metal Arc Welding of Copper Alloys," by Mr. Ira T. Hook, and finally third phase of fusion welding known as atomic hydrogen welding under "High Tensile Atomic Hydrogen Arc Welds in Alloy Steels," by F. Ray.

To begin with the thermit welding process we have witnessed the stern frame of the Coastguard Cutter Northland after it has been in service for a number of years as pictured in the paper and have found out that this type of fusion welding has proved very satisfactory. Also have witnessed numerous thermit welds, especially those made by Newport News Shipbuilding and Drydock Company and found in every case where this phase of fusion welding was used that same stood all tests of service entirely satisfactory.

Of the second paper by Mr. Ira T. Hook, entitled "The Metal Arc Welding of Copper Alloys," it is with a great deal of interest that I read of the advantage and the continued advantages of the welding of copper alloys, especially Everdur material. Back in 1928 necessity caused the electrical industry, especially the company with which I was formerly affiliated, to research for a material of non-magnetic origin and studies were made extensively upon this particular grade of alloy. At that time the research developed that Everdur had all the possibilities which were required in the electrical industry at that time, with reference to non-magnetic properties, etc., which we had to use particularly for backing and side sheets in our housing compartments. At that time Everdur had just been put on the market and oil would ooze out of some of the welding seams. By continued experimental work for six months at that time the American Brass Company, through the efforts of their Mr. Jacobs developed a rod that was uniform, free from seams and other defects from which we could make a good solid weld which was free from porosity.

It was also developed that we had considerable strength in the welds, as you see in Fig. 2 of Mr. Hook's paper, a high tension circuit breaker dome made up of steel with Everdur inserts to break up the magnetic flux. The tests made at this time prove we could properly weld Everdur and steel satisfactorily with the Everdur rod.

Investigation of fluxes at that time resulted in a flux which consisted of 90 per cent fused borax and 10 per cent sodium fluoride. Advancements in welding are the results of research into the various alloy rods, and for this reason we are mighty glad to hear of the further experiments which have been accomplished with copper alloy materials which we in the welding field today are very anxious to secure and to properly weld.

We were very interested in the last paper on "High Tensile Atomic Hydrogen Arc Welds in Alloy Steels," to find out the ease with which Mr. Ray pulled these test specimens and the manner in which he made up his specimen, especially using the drill hole specimens instead of the orthodox method of using the standard 2-in. x ½-in. threaded specimens, which is a very expensive and lengthy method for running tests.

All the papers presented are of special merit to the society members and I wish to thank the writers for bringing them here to the Society, particularly from the standpoint that it is hoped in the coming meeting the American Welding Society will have a paper or two presented upon the proper method of making and using welding wire from one of the various manufacturers of welding wire.

CHAIRMAN OEHLER: It is gratifying to hear the comments on all three papers from a man who represents a user and who naturally is one of the most powerful stimulants to the activities of men such as have presented the papers here.

MR. E. VOM STEEG, JR. (General Electric Co.): I would like to ask Mr. Hook a question as to what experience he has had in the welding of so-called extruded metal, which is yellow brass.

MR. HOOK: We made quite a number of experiments in the welding of extruded metal which carries a rather high percentage of zinc, about 40 per cent of zinc, and 2 or 3 per cent of lead. For a considerable period we thought that the lead was the element which was giving us the greatest trouble in getting porosity in the weld metal and we thought it was the lead which was boiling out, since it does not go into solution in the copper alloy and was giving us porosity More recently we have had better results. The best results that we have had in our experimental work at the American Brass plant have been with the use of the oxyacetylene torch and the use of welding rods similar in nature to Tobin bronze, but varying slightly therefrom.

I do not like to give any particular analysis at this time because we are still working on that and I think in a very short while we will have something to publish on it. Tobin bronze melts at around 1610 to 1625 deg. Fahr., just about the same temperature as the base metal, the extruded bronze. The extruded bronze has very nearly the same color, but it is desirable to have a rod which melts at a slightly lower value than that and which will flow good and not cause so much boiling out of the zinc or the lead in the base metal.

We have also had some fairly good results with the carbon arc torch. The carbon arc torch is rather an old form of welding, but has been improved recently by at least two workers, one of them, a Mr. Hanson out at Milwaukee, and we obtained some very satisfactory welds in extruded metal, using the same composition weld rod. In fact, we used a piece of the base metal for a weld rod, the same composition. There will be something more on this topic in the near future.

MR. G. F. WIESER (M. W. Kellogg Co.): I would like to ask Mr. Croll one question. His slide showed very clearly how the welds were made on the outside edges of these elements, but it is a question in my mind how you make them on the inside, as the electrodes might offer some difficulty.

MR. CROLL: They are welded first in pairs on the inside. They are set in a jig and rotated and the arc is played on the inside edges. This is, of course, the smallest size and is the most difficult to make. However, it can easily be done because the plates are rotating around with the two plates clamped together while the man holds the arc at the bottom of the inner periphery of the plates. The inside weld seems to be easier to make than the outside weld because of the concavity of the inner periphery which helps sustain the molten metal.

MR. ALEXANDER: I would like to ask the first speaker to give the composition of the steel which cannot be machined but ground. It is a very high manganese steel generally.

MR. TINNON: I don't know the exact analysis of the particular steel that might be used for the wobbler ends. We make a thermit that we call wobbler thermit which is very high carbon steel and the resultant steel has a very high percentage of manganese. I

don't remember just exactly the analysis of the resultant steel.

MR. ALEXANDER: I would like to ask the same speaker—you mentioned that the cooling of the weld proceeds from the inside out. I wonder if you could say a few words more to give us a clearer picture of how it happens.

MR. TINNON: The reason that the weld cools from the inside—

CHAIRMAN OEHLER (interrupting): May I ask as a rider to that question—after you have discovered that the weld cools from the inside out, you have developed a means which improves the weld and reduces the necessary amount of metal in the weld. Would you add some information on that to your explanation?

MR. TINNON: I can probably more clearly show you that if I put on a slide. I will refer you to the photograph on page 6, Fig. 10. You will see that is a cross section through a weld made with the present process. You can see the fusion lines, the darker areas. In the older welds we used a very much larger quantity of thermit, the fusion lines were a great deal wider and the collar of the weld was something over twice as wide as this present collar, so that the fusion line was considerably over double what this is. The parent metal was melted down to a much greater extent in the center of the weld. Now the large section of the parent metal conducts the heat away from that smaller area of hot metal much more rapidly than the heat is conducted away from the periphery of the weld where there is a greater amount of hot metal. That center section of the weld freezes before the outer section is frozen and we found what we have termed for want of a better name a cleavage plane. We call it a cleavage plane and we found in large welds a crack or flaw in the center of those welds due to that difference in cooling.

By reduction of the size of the weld and reducing the size of the collar, using a much smaller amount of material, about 60 per cent less, we found that we reduced that difficulty of the heat remaining on the outside periphery of the weld much longer than it did on the inner periphery. We equalized tthe cooling more and got away from that cleavage plane which solved a great majority of our troubles.

We were following originally the old foundry custom, not realizing that the more we tried to feed the shrinkage with the hot metal the more trouble we got into.

MR. R. E. WAGNER (General Electric Co.): In Mr. Hook's paper on the welding of Everdur, he makes reference to Everdur panels in the side of transformer tanks. The reason for using Everdur, as has already been mentioned, is to provide a section in the tank wall which is non-magnetic and thereby reduce the magnetic losses due to heavy currents passing through cables brought out of the side of the transformer.

We had occasion to place in the side of a tank made of ¼-in. thick steel an Everdur plate approximately 12 in. square. Difficulty was experienced in doing the welding on account of the fact that the coefficient of expansion of Everdur is very much greater than that of steel. When the molten metal along the edges of the panel cooled, cracks developed in the weld. We were at our wits' end to find a way out.

Finally a steel frame was made about an inch larger than the square of Everdur. The Everdur was welded into the frame. This set-up gave the stresses developed in cooling an opportunity to pull in the yielding sides of the frame and thereby avoid cracking the weld.

The framed panel was set in the wall of the steel tank and welding was done steel to steel. With this procedure we have succeeded in placing the panels as required.

There was another problem of a similar character requiring a smaller section of Everdur plate. The space between two 2-in. holes in the side of a tank, was fitted with a small section of Everdur plate to give it non-magnetic properties desired. Something like 160 amperes with 5/32-in. Everdur electrodes were used to weld the seams. The upper seam was welded first and then the lower seam. Either during the process of welding or a little later, cracks would appear in the joint. The difficulty was finally overcome by using less current, 125 amperes, with a special manipulation of the electrode.

So that in the use of Everdur plate as an insert in steel plate, one must give careful consideration to its large shrinkage characteristic and provide a setup that will allow, as far as possible, the release of stresses.

MR. H. A. WOOFTER (Swift Electric Welder Co.): It might be interesting to emphasize a point brought out by Mr. Hook in his paper, namely, that copper when hot has an enormous affinity for oxygen, and, to point out something that might save some of you from making an error, I would like to take just a little bit of time. Suppose you are welding a copper strip and were going to wind it into a coil for a motor field or something of that kind. Between these turns is insulating material. Suppose that at some place this copper had been spliced by means of some slow-welding process. In order to prevent oxidation a phosphorus enveloping flux has been used. The enveloping flux, we will admit, keeps out the oxygen largely, but in turn the hot copper will absorb phosphorus.

Now, then, 1 per cent of phosphorus at any point in copper cuts its conductivity down 52 per cent, leaving it 48 per cent. Supposing it will cut down the conductivity to 48 per cent; what occurs? Using your formula for heat you will find you are going to have a hot spot in the conductor at the weld which in time (it may not do it in one month or two) will char the insulation and burn it and after a while there will be a failure in the coil at that point owing to the absorption of phosphorus.

I have seen many cases of that nature so that I do not permit any use of phosphorus as a flux in any copper conductor that is going to be used in a coil of any kind whether for an armature or a field or anything of that kind.

Now, you can easily see that, since hot copper absorbs oxygen, the longer you keep the copper hot the more oxygen it is going to absorb. So that I would like to urge on you in all cases when you make a weld in copper at any time that you make it just as quickly as possible. The same way with yellow brass.

You realize that when a weld is made slowly in brass which usually is 66 per cent copper and 34 per cent zinc, if you are making it slowly by a torch or a flame, as soon as you pass 900 deg. the zinc tends to volatilize out and burn out and go up in a beautiful blue smoke and when you get to 1891 deg. you have nothing left but spongy copper and you get a red short structure at the weld, which hasn't strength or conductivity either.

So there is another case where the alloy should be welded just as thickly as possible, and when that is done, the zinc has no time to volatilize and a photomicrograph of such a weld will show the same identical structure as any other part of the work. The same is true of aluminum and is true in less measure of practically all of the alloys that the quicker you weld them the less oxidation occurs.

CHAIRMAN OEHLER: I feel very much pleased to think that under the circumstances, namely, the Friday morning after Thursday or banquet night, we can create so much in the form of intelligent and lively discussion. I do not want to press for it unnecessarily, but I also do not want to exclude any one from asking questions about things he would like to know and I would like to hear more such information as we have been receiving.

MR. F. E. ROGERS (Air Reduction Sales Co.): I am not going to discuss welding, but I would like to ask the speaker who talked about atomic hydrogen welding of an expansion joint, how durable is this form of expansion joint; is it long lived?

MR CROLL: You mean from the standpoint of number of movements or from the standpoint of corrosion of the element?

MR. ROGERS: No, rather from the standpoint of average period of installation. Is it good for a year or five years or ten years?

MR. CROLL: A former company made this expansion joint for a short period and we have recently received some orders from the same customer who has had one in service for five years. He has never had any trouble whatsoever and that was made by another type of welding which we have tried out and consider inferior to this type. This is the only type we have ever found that will leave the actual structure of the weld the same as the plate themselves, although we don't say that there aren't other methods. This is the only one we have found so far.

MR. ROGERS: I was particularly interested in the type of construction because a company now absorbed by our company demonstrated the possibility of making this type of joint more than twenty years ago, and had quite some business at that time for a small company. The expansion joint and the assembly as a whole being made feasible because of oxyacetylene welding.

CHAIRMAN OEHLER: I might add, Mr. Croll, a question. Have you in your experience had welds or structures of this kind fail due to either fatigue or corrosion?

MR. CROLL: No. The only failures that we get are when it so happens that the weld is not made thick enough. The welds have all been uniformly good. There doesn't seem to be any difference in the quality of the welds themselves. The heat treatment, of course, gets rid of the crystalline structure and if the weld is made properly it will not break. In other words, we find from breaking many samples that when the weld is properly made the element fails in the plate and not in the weld. That is in the plate next to the weld.

CHAIRMAN OEHLER: Presumably then testing under pressure would detect that kind of a flaw.

MR. CROLL: Testing under pressure is not a very good method. We have a machine in which we vibrate these expansion joints. The pressure stresses are much less than the movement stresses and, of course, as Mr. Ray explained in his paper it is necessary to use a high elastic limit material to allow the high stress in the weld and plate.

MR. W. B. MILLER (Union Carbide & Carbon Res. Labs.): I should like to ask Mr. Croll first if they made any ductility measurements on their machine. I should judge that your gage length was about 1½ in. Did you do any ductility measurements, elongations on those all welded specimens?

MR. CROLL: Not that I know of. Mr. Ray could answer that question. I, unfortunately, don't know everything that he has done along those lines. The results seem to show though that from the elastic limit and the uniformity of the elastic limit of the weld, as compared to the plates, the ductility of the weld is just about the same as the plates.

MR. MILLER: You have a high elastic ratio in some cases equal to the tensile. So I surmise your ductility is quite low in those welds. In reality this joint is really a compression joint rather than an expansion joint. So you won't be bothered with fatigue. You get that narrow notch in between the two. The joint is put in cold.

MR. CROLL: It is now in its neutral position there, and when it is installed it is installed with half its movement out and when it takes its full movement it moves to the innermost position in which case the joint is at its maximum strength. It would be in its weakest position naturally with pressure applied and stretched out to its outmost position. But, of course, the structure is so made that it is capable of sustaining the pressure under those conditions.

For instance, in a hot water line that condition might often occur, in a building where there was pressure on at all times. The water and piping might get cold and the joint would be in the extended position.

MR. MILLER: I should like to ask Mr. Hook if he has any preference for either silicon or phosphorus for de-oxydizing copper or base metal.

MR. HOOK: I think there isn't a great deal of difference. Phosphorus is almost universally used as a de-oxydizer of base metal.

MR. E. R. BENEDICT: I would like to ask Mr. Croll in the mechanical tests of the joint how many oscillations or cycles it goes through before you get failure.

MR. CROLL: We haven't gone far enough to give you an exact figure. We have run some of these 2500 or 3000 movements. We find that if we make a weld that isn't strong enough, if it is thinner than the plates, and the joint is put in a testing machine, it fails almost immediately. It fails with the movement of ten or fifteen or twenty movements. It takes very few movements when the weld is thinner than the plates. But when it is thicker than the plates, it seems to be indestructible.

MR. BENEDICT: Is every joint tested before it is shipped to the consumer?

MR. CROLL: We test the joints now in the testing machine and then subject them afterward to a very high pressure test before shipment.

MR. BENEDICT: How many oscillations are given in the test before being shipped?

MR. CROLL: About 500, which, of course, in the ordinary course of events, would represent a very long life for the joint in many installations, but we are continuing now with some experiments that are running on joints that we haven't broken to determine just where that breaking point is. We have also subjected these joints to actual steam pressure tests

under movement, which tests ran about2000 movements, and it took so long to conduct this experiment that we finally moved the joint beyond its rated movement until it finally broke near the outer periphery of the plates next to the outer weld.

MR. BENEDICT: What is the maximum temperature the joint is designed for?

MR. CROLL: If it is heat treated at 750 deg. Fahr. it can be run at that temperature, of course.

MR. BENEDICT: I meant how hot superheated lines would you recommend the use of this joint?

MR. CROLL: Seven hundred fifty. In which case we would draw it at a little higher temperature and would allow more plates because, of course, the steel would not then have as high an elastic limit. We would probably have to draw it at 800 or 850.

MR. BENEDICT: A low-temperature, low-pressure joint would not be the same as you would sell for a high-pressure, high-temperature job. A joint is for individual service.

MR. CROLL: We have certain standards. That, for instance, is a 150-lb. joint. We have 250-lb. joints. They, of course, have thicker plates and more of them are required to take the same movement.

MR. G. H. MOORE (Welding Office, Production Dept.): In order that a ship may be constantly in service and that her earnings may be profitable, it is frequently required of a shipyard to make quick repairs of good quality. Recently a Chesapeake Bay steamer had to have a new rudder in a very short time. The original rudder stock was usable, so a new rudder frame was quickly forged in sections and the rudder stock and the frame parts joined by means of five thermit welds. Plates were metal arc welded to each side of the frame and the rudder delivered well ahead of schedule. This was in the nature of a new part.

New All-Welded Rolled Steel Gear Blank

By D. D. SPACKMAN

✦ Mr. Spackman is President of Lukenweld, Inc., a subsidiary of Lukens Steel Co.

THIS company, which is primarily engaged in the design and manufacture of welded steel assemblies for machinery and equipment, has developed and is now manufacturing all-welded rolled steel gear blanks for use in the manufacture of cut gears. This gear blank is the culmination of a considerable period of research and experimental work.

The welded steel blank, which can be employed in the manufacture of spur, herringbone and helical gears, can be made any size from 24-in. outside diameter up. The largest all-welded gear blank made up to the present time is one with a shipping weight of 4350 lb. It is of 66¾ in. outside diameter, 11¾ in. width of face, 4⅛ in. thickness of rim, and 22½ in. diameter hub.

While the all-welded gear blanks are ordinarily made entirely from S. A. E. 1020 carbon steel, the rims can be furnished in steels of special analyses if desired.

The hubs of the all-welded gear blanks are first gas-cut from solid rolled steel of the thickness to give the desired hub diameters. The webs are gas-cut from rolled steel plate, as are the ribs, the latter being formed into channels of the required section. The webs are arc welded to the hubs, and the reinforcing channels are welded to the web structures. The final operation consists of the circular bending of the gear ring, and arc-welding in position to form the finished gear blank. Before shipment, all of the welded gear blanks are carefully and thoroughly annealed, under pyrometric furnace control. Welding operations are under rigid procedure control and in accordance with insurance welding practice.

In the manufacture of all-welded gear blanks, no patterns are required, as the gas-cutting and arc-welding are done with blueprints of the gear design as the guide. This feature, in addition to elimination of the pattern cost, permits prompt manufacture and shipment, since no time is required for pattern-making. This time-saving is an important advantage in filling requirements occasioned by gear breakdowns.

The major advantages of the all-welded gear blank, however, from the standpoint of both the gear manufacturer and the gear user, are the purity and homogeneity of the thoroughly-annealed rolled steel from which the gear blanks are made. Rolled steel, as is well-known, is characterized by marked freedom from blowholes, gas pockets, hard or spongy spots and other defects. The gear

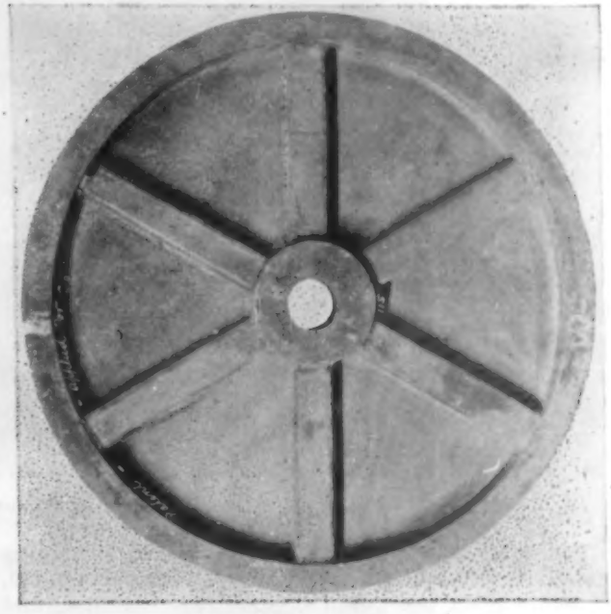

Fig. 1—All-Welded Gear Blank

rings, therefore, can be uniformly cut, and the cut teeth are sound in structure. These features minimize the losses of machining time, labor and gear material which might otherwise be caused by defects in rings discovered only after considerable cutting work had been done, frequently causing the scrapping of partially-cut gears, Moreover, the life of hobs and other gear-cutting tools is said to be increased because of the tendency toward less wear in cutting on sound and homogeneous rolled steel.

Welding Brass and Copper Piping

By DeW. ENDICOTT

✦ Mr. Endicott is connected with the Linde Air Products Co.

BRASS and copper piping and tubing are being used in constantly increasing amounts for the construction of water lines in office buildings, hospitals, universities, private residences, in short, anywhere where a permanently trouble-free water supply system is desirable. The preference for brass or copper for water service is due, of course, to the fact that copper and its alloys do not rust and are highly resistant to corrosion.

The advantages of welded construction for piping installations have long been recognized and applied, particularly in the fields of steel, wrought iron and cast iron pipe. Recent developments now make it possible to apply welding with equal advantage in joining brass and copper pipe.

Welding offers a number of advantages over the conventional method of jointing brass or copper pipe. The wall thickness of a threaded piece of pipe must be heavier than a welded pipe, assuming the same pressure conditions, because the wall must be heavy enough to take a full depth thread and still leave sufficient thickness to carry the pressure. In other words, if the pipe has sufficient metal at the bottom of the threads there is an excess of metal over the rest of the length, whereas with welded tubing there is no reduction of cross-sectional area, so thinner wall pipe may be used to carry the same pressure and as material is money, the cost of tubing for welded water systems will be appreciably less.

With welded pipe the joint becomes an integral part of the pipe and is equally as strong as the base metal. No dependence is placed on white lead or on the closeness of the mechanical fit to insure a tight joint. This is of particular value where lines are run in inaccessible places or set in concrete where repairs could be made only with extreme difficulty.

Anyone who has had experience with piping installations has faced the difficulty of being held up by the lack of proper fittings at one time or another. There are times when a delay of this nature may mean the difference between completing and not completing a contract within the time limit, which in turn results in either profit or penalty. With welded construction such a condition cannot exist as long as there is a supply of tubing on hand since all bends, tees, and reducers can be fabricated from pipe.

Fig. 1—Copper Water Tubing Bronze-Welded

An exhaustive investigation was recently made by our company to determine the most desirable type of design for joints in copper and brass tubing, the best welding procedure, the most suitable welding rod, the weldability of the joints in various positions, and the relative strength of the various joint designs. The results of this investigation have served as standard practice procedure in the bronze-welding of copper, red brass, Alpha brass and Munz metal tubing.

Copper Tubing

The laboratory investigation of the welding of copper tubing included tests of butt-welded, long-bell and short-bell type joints. Tests were conducted with a Special Cupro Welding Rod for fusion welds

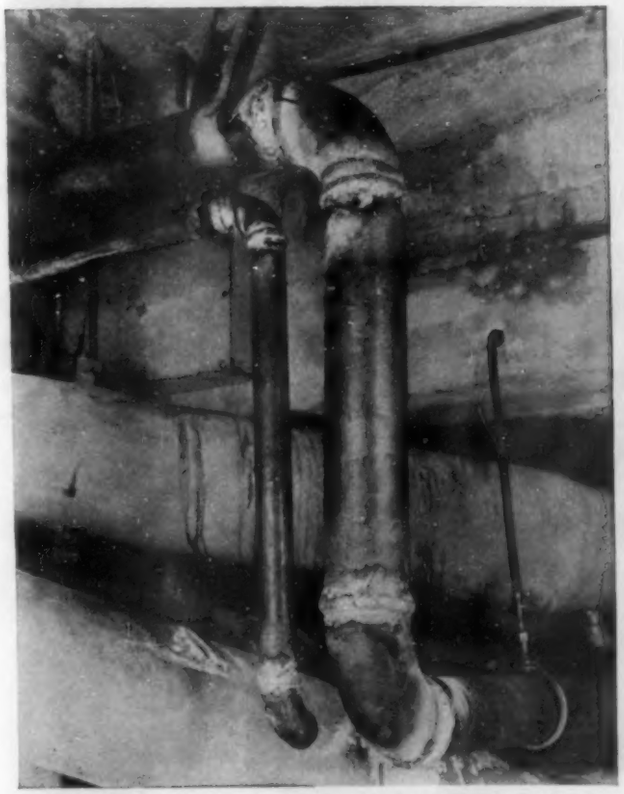

Fig. 2—Welded Brass Hot Water System With Short-Radius Turns

and with a Patented High Strength Bronze Welding Rod.

The belled joints were formed by driving a dolly or tapered plug into the pipe until the desired shape had been obtained. Although this method was perfectly satisfactory in the laboratory, a better method for obtaining a short-bell is to flare the end of the pipe on the horn of an anvil using a wooden mallet. This may be done by hand and will not require any special equipment. Since the tensile tests showed that the short-bell type of joint was as strong as, if not stronger than the long-bell, this latter method is not recommended. The short-bell is naturally more economical since less of the pipe metal is overlapped at the joints.

It was found that welds developing the full strength of ¾-in. copper water pipe could be obtained by using either the special cupro welding rod or the high strength bronze welding rod. The tensile strength of the pipe metal as annealed by the welding heat averaged 29,200 lb. per square inch. The bell type joint proved superior to the butt joint when the pipe was welded in a vertical position, and both types proved satisfactory for making a horizontal position weld. The bronze weld, however, was found to have a distinct advantage over the fusion weld since the weld metal from the former solidified less rapidly, making the weld easier to control to avoid porosity.

In the case of 1½-in. copper water tubing the bell type joint made with bronze-welding rod proved to be decidedly stronger than joints made with copper rod whether the joints were made in a vertical or horizontal position.

Red Brass

Tensile tests were made on 1-in. and 2½-in. red brass pipe with both bell and butt type joints welded with High Strength bronze welding rod. In the tests on the 1-in. pipe, the bell joints all broke in the base metal adjacent to the weld at an average strength of about 39,000 lb. per sq. in. which is the strength of red brass pipe when annealed by the welding heat. All of the butt joints broke at low strength either through the weld metal or along the scarf. The bell type of joint is therefore superior for either vertical or horizontal position welds.

The results obtained on 2½-in. red brass were practically the same as those obtained with the smaller diameter tubing. An additional test was made on the larger size pipe by using strips cut from the base metal as welding rod. This was unsatisfactory as the weld metal proved difficult to control and developed porosity.

Alpha Brass

In spite of the rather low melting point of Alpha brass, it was found that the bronze weld metal could be flowed along the joint in Alpha brass without bringing the base metal to the melting point. The welding operation was therefore easily controlled, since porosity, which develops in the base metal when yellow brass is melted, was avoided. All of the bell-type joints welded in both horizontal and vertical positions broke in the pipe metal at the full strength of Alpha brass annealed by the welding heat. Unsatisfactory results, however, were obtained with butt joints not only from the point of view of strength but also because of the difficulty in preventing the weld metal from protruding into the inside of the pipe.

Muntz Metal

The welding of Muntz metal presents an entirely different situation from that presented by any of the

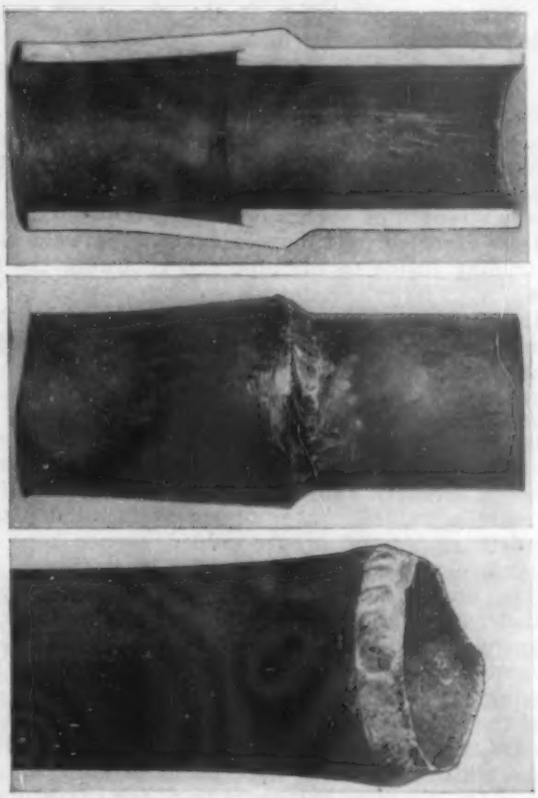

Fig. 3—Short-Bell Type Bronze-Welded Joint in Red Brass and Result of Tensile Test

other copper alloys previously mentioned, for the melting point of this alloy is as low as that of the bronze-welding rod. Welds made in Muntz metal with bronze-welding rod are therefore true fusion welds. The laboratory tests were made on 1-in. diameter Muntz metal pipe using High Strength bronze welding rod. The short-bell joints were found to have a strength of about 36,000 lb. per square inch, which is more than sufficient for the average service of water pipes.

The use of an excess oxygen flame improved the appearance of welds in this metal but resulted in increasing the undercutting in the pipe when vertical welding was performed.

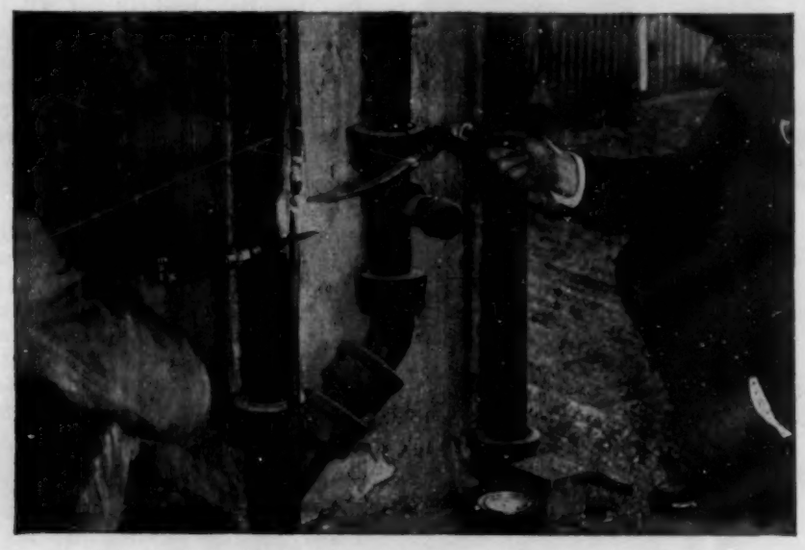

Fig. 4—Bronze-Welding Branch Connection in Copper Water System

General Recommendations

These investigations indicate that the types of copper and brass pipe and tubing in general commercial use can best be welded by using the short-bell type of joint and High Strength bronze welding rod. The tensile strength of such joints is entirely satisfactory and the inserted pipe insures against the weld metal protruding inside of the pipe and retarding the flow of water.

The recommended procedure as developed by these investigations has already been applied under field conditions in a number of installations.

Bronze-Welded Copper Water System

An interesting installation of bronze-welded copper tubing was recently completed in the office building of a Southern railroad. This building contained not only a welded copper steam system but also a complete system of bronze-welded copper pipe for hot and cold water supply lines for lavatories.

This was the contractor's first experience with welded copper plumbing and he took full advantage of an oxy-acetylene service operator's knowledge to aid him in developing special tools for bending and swaging the tubing. The service operator also supervised the start of the job, instructing the contractor's welders in the proper procedure for bronze-welding. Tongs with heavy jaws were made to flare out the ends of the risers or branchers to fit the curvature of the header or larger pipe when a tee connection was to be made. These heavy jaws were cut out in such a manner that by holding the end of the tube in the tongs and hammering it with a ball peen hammer the wall of the tube would be bent down into the recess in the jaw which conformed to the curvature of the pipe where the tee was to be attached. A number of these tongs were made to fit the different sizes of tubing used. A special tool was used as a drift to bell the ends of one tube to permit the entrance of the other. In welding, the bronze was run down this joint making a strong bond free from porosity.

A small fixture was designed to hold carbon blocks on the back side of the joint, causing the blowpipe flame to curve around the joint and heat it uniformly, thereby speeding up the job and removing any possibility that one side would not be properly bronze-welded. In this case, some moistened flux was placed in the joint, which was then heated with the rod held on one side so that the bronze would flow around the joint. Examination of sample welds showed that bronze had run between the overlapping tube sections where the flared-out portion fitted over the inserted pipe and proved that perfect adhesion had been obtained. With this type of joint there is no possibility of icicles or protrusions forming on the inside of the pipe wall. It was absolutely necessary that this be a perfect job, as a great part of the tubing was to be buried in concrete.

Remarkable speed was made with the actual installation work as the tubing could be snaked around I-beams and easily bent to conform to any desired shape. All joints were welded with $\frac{1}{8}$-in. diameter high strength bronze welding rod.

Use of Brass Short-Radius Turns

The short-radius turns designed especially for welding which are so extensively used in welded steel and wrought iron piping installations, are now available in brass. Use of these turns simplifies the design and construction of welded brass piping systems. The short-bell type of joint can be applied easily, the end of the straight length of pipe being flared in each case to fit over the end of the short-radius turn.

This design has been used effectively in a recent

installation in a large hospital. The entire hot water system is Muntz metal pipe ranging from 1½ to 6 in. and brass short-radius turns are used throughout. The system is designed for a working pressure of 90 lb. per square inch.

SPECIFICATION FOR BRASS PIPING

To meet the general demand for specifications covering the oxy-acetylene welding of steam and hot water brass piping in the industrial and building fields, our company has prepared the following recommended specification which may be added to or incorporated in any general specification for piping installations of this type.

General

I. Where welding is used as a method of construction these welding specifications shall apply to the welded design and welded construction of the specified piping system and are supplementary to and a part of the other specifications covering the installation. The general requirements, mechanical equipment and engineering features covered by other sections of the specifications are in no way affected by these welded piping specifications which apply only to the substitution of welding for other types of joint construction in the specified piping.

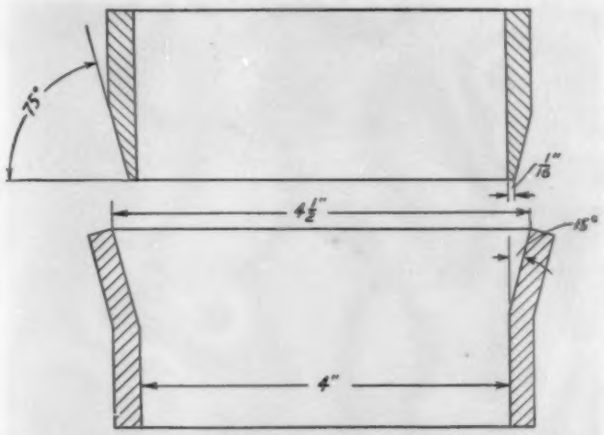

Fig. 5—Preparation of Brass Pipe for 75 Deg. Bevel Short-Bell Joint

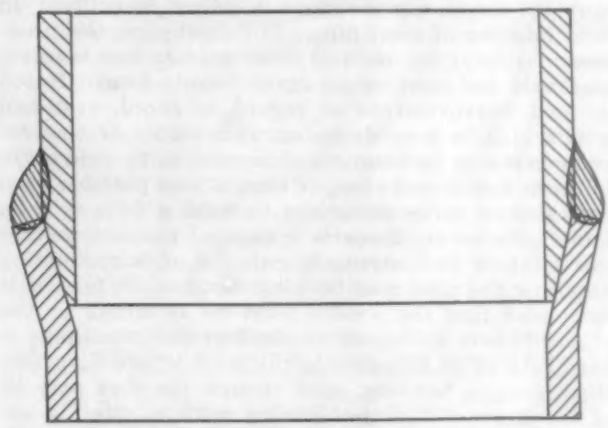

Fig. 6—Recommended Design for Welded Short-Bell Type Brass Pipe Joint

Process

II. All welded joints shall be made by the oxy-acetylene process.

Welding Rod

III. The welding rod for brass pipe shall be our special high strength bronze welding rod. Brazo Flux shall be used as fluxing agent.

Competency of Welders

IV. All welding shall be done by competent welders in a thoroughly first class, workmanlike manner.

V. The contractor, if requested, shall furnish proof of the competency of his welders in the following manner:

Each welder who will be required to weld on the specified piping shall, in the presence of the owner or his representative, before any welding is done in the installation, make a typical welded joint. A joint of the largest size pipe to be used in the installation prepared in the manner shown on the drawing from pieces of pipe approximately 8 in. long shall be considered typical. The welding shall be done with the joint in position, i.e., without rotating the pipe.

Each sample joint shall be cut in strips longitudinally so as to contain the weld in the center. The strips shall be fractured by placing in a vise with the weld center line even with the top of the vise and striking with a hammer against the side of the strip opposite the reinforcement. The fractured weld shall show complete penetration to the bottom of the fillet or vee and complete fusion to the sides of the fillet or vee. The weld metal shall be sound, free from porosity, gas pockets and cold laps.

Line Joints

VI. All line joints shall be of the short-bell and spigot type shown on the drawings covering this part of the work. The reinforcement shall be at least the amount indicated.

Welded Fittings

VII. Welded Tees or Y branches shall be made by first cutting the opening with a circular saw to a size corresponding to the inside diameter of the nipple. The end of the nipple shall be cut to fit the external diameter of the main line pipe. The dimensions of the completed weld shall be substantially those shown in drawing illustrating this type of connection.

Testing and Repairing Leaks

VIII. All welded lines shall be tested at 50 lb. per square inch hydrostatic pressure unless one and one-half times the working pressure exceeds the above amount. In this case the higher pressure shall be used.

IX. All leaks found on test shall be repaired by welding, no caulking being permitted.

Welding of Cast Iron Pipe

By T. W. GREENE

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THE phenomenal expansion in the laying of welded pipe lines, particularly in the petroleum, manufactured and natural gas industries, one bright spot of industrial activity, last year, focused the attention of the engineering profession on the extent to which oxy-acetylene welding is utilized in field jointing of steel pipe. For steel pipe, the progress of joining by oxy-acetylene welding has been remarkable and continuous developments have effected decided improvements in regard to speed, cost and quality. It is possible today, as a result of new developments in technique and invention, to weld a 20-in. joint faster and cheaper than it was possible even only two or three years ago to weld a 6-in. or 8-in. joint. Moreover, there is a general realization that the joint is full strength, capable of withstanding anything the pipe may be subjected to. In fact, it is demanded that the welded joint be as strong as the pipe. This is evidenced by the fact that steel pipe is bent cold at or adjacent to the weld wherever conditions require bending, even though the pipe may be of the highest strength, having a yield point in excess of 50,000 lb. per sq. in. and an ultimate strength in excess of 80,000 lb. per sq. in., which to be cold bent necessitates full strength joints.

What is not so generally appreciated is that cast iron pipe can be welded, that a joint of full strength can be made, and that there are many conditions where cast iron pipe can be welded economically to advantage.

The welding of cast iron pipe, due to the inherent characteristics of cast iron, is different from steel welding, cast iron pipe being generally bronze-welded. This application is not brazing, but welding, inasmuch as it requires the usual welding manipulation and technique. The welding rod used, however, instead of being cast iron similar to the base metal, is bronze, normally of the 60 per cent copper and 40 per cent zinc type.

Bronze-welding of cast iron pipe naturally first began to be used as a reclamation application. It was used to repair cracked or broken pipe, valves or other fittings. Fig. 1 shows the repairing of a large gate valve, the application resulting in a saving of several hundreds of dollars. The natural step and sequence from the use of bronze-welding for reclamation purposes was its application in production. Most of the cast iron pipe manufacturers are in a position today to furnish cast iron pipe double-lengthed and in some cases triple-lengthed by bronze-welding. They all can supply pipe properly prepared for welding. Bronze-welding has been used most generally, as is to be expected, in the gas industry than for water lines, for in the gas industry there is a strong economic demand for a permanently tight joint which has not been met by the bell and spigot or other types. For industrial or special process piping, requiring cost iron pipe construction, bronze-welding offers an economic advantage particularly in replacing expensive flange joints and as such installations are amply supported and properly designed, they are especially adapted to the use of welding.

It may be of interest to explain why cast iron pipe is usually bronze-welded instead of cast iron welded. Cast iron pipe can be welded with cast iron welding rod, but due to the brittleness of cast iron it is necessary to use proper precautions in the way of preheating and subsequent even cooling in order that strains may not be set up which might cause cracking either of the base metal or the weld. This, of course, is rather impractical for most field uses. There are two main fundamental reasons why bronze-welding can be done successfully without the precautions otherwise necessary for cast iron. One is the lower temperature at which bronze-welding is done. In cast iron welding with cast iron rod, the base metal must be melted, requiring it to be heated to above 2100 deg. Fahr. In bronze-welding the base metal need be brought up only to a bright cherry red as the melting point of bronze welding rod is about 1620 deg. Fahr. and the temperature required for proper tinning of the bronze to the cast iron is somewhat below this. This decidedly lower temperature, of course, minimizes the total expansion-contraction and accompanying strains. The other fundamental factor is due to the physical properties of the bronze at higher temperatures. Fig. 2 shows the effect of temperature on the tensile properties of 60-40 copper-zinc bronze somewhat similar to that used in welding. It will be seen that the strength of bronze, unlike cast iron, falls very rapidly with increased temperature and that bronze has very little strength above 600 deg. Fahr. In welding cast iron with bronze, consequently, the weld and heated cast iron can cool with no resistance from the bronze-weld until cooled below 500-600 deg. Fahr. Therefore the strains that might otherwise be locked up as a result of expansion-contraction are prevented. It is for these reasons that bronze can be used to weld cast iron without necessitating preheating, without causing cracking or without setting up excessive strains in welding.

Fig. 1—Bronze Welded Reclaimed 36-In. Gate Valve

The tensile strength of cast iron is about 20,000 to 30,000 lb. per sq. in. and the strength of the pipe as measured by modulus of rupture in bending is from 20,000 to 30,000 lb. per sq. in., depending upon the process of manufacture, pipe diameter and other fac-

tors that affect the physical properties. The strength of ordinary bronze weld metal is 40,000-50,000 lb. per sq. in. There are available improved bronze welding rods which give 10,000-15,000 lb. higher

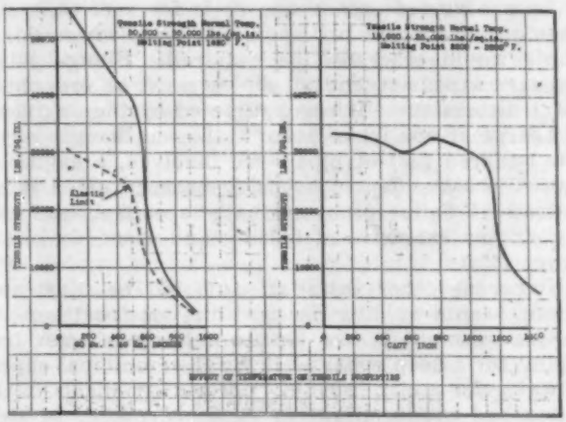

Fig. 2—Effect of Temperature on Tensile Properties of Cast Iron and 60 Cu-40 Zn Bronze

strength and welds of very much denser structure, as in these improved welding rods, alloying and deoxidizing elements are included which minimize oxidation of the zinc and improve their general welding characteristics. As the strength of the bronze rod is very much higher than the base metal, and as bronze can be used without fear of injuring the cast iron, the essential features in obtaining a proper joint are securing good tinning or adhesion of the bronze to the cast iron and perfecting a design to produce uniform transfer of forces between the parts joined without concentration of stresses.

Strain gage measurements across a bronze-welded vee joint of full size pipe joints under tensile tests show that the deformation and stress at the joint is similar to that in the pipe and that there is no concentration of stresses to cause weakness. Some five or six years ago, when bronze-welding of cast iron pipe was first tried, plain square end pipe was used and a weld or collar deposited on the outside of the pipe, bridging the joint. But it was found that there was a decided stress concentration in the cast iron adjacent to the weld, which was inherent with this design not from any feature of welding, but as a result of pure mechanics of the transfer of forces. Stress-strain measurements show a deformation and a stress across the weld of twice the intensity of that in the pipe away from the joint. Tests made on full size pipe, both in tension and bending, further confirmed the weaknesses of this design, as the strengths obtained were only about half that of the pipe.

Extensive research has been made of the strength of different types of joints. In testing full size pipe joints in transverse bending, two sections of pipe bronze-welded together are tested as a simple beam by supporting the pipe on rollers and applying the load directly on the weld in a suitable testing machine. Under such a test the maximum bending moment and stress are imposed at the weld and failure may be expected at, or adjacent to, the joint. By making similar tests on pipe lengths without joints, the relative strength of the weld to that of the pipe, or the joint efficiency, can be determined.

Such tests made on simple vee joints have shown that the strength of the vee joint is about 75 to 90 per cent of the strength of the pipe. Full strength is not quite secured with such a design. Failures occur parallel to the vee, the bronze pulling off a thin layer of cast iron when the joint has been properly tinned. The perpendicular tensile adhesion or bond of the bronze or of a thin layer of cast iron directly under the bronze to the main body of the pipe does not seem to be sufficient to outpull the pipe. To strengthen this bond, a shear vee area should be added, as shown in Fig. 3. To break the bond between the bronze and cast iron with such a design, it is necessary to rupture not only the tensile adhesion along the vee but in addition to shear the bronze from the cast iron along the shear area or shelf. This combination design is known as a shear vee joint. The table in Fig. 3 shows results of bend tests with this type of joint in deLavaud pipe, an extensively used pipe which is cast centrifugally. It will be seen that the full strength of the pipe is developed. Fig. 4 shows results of joint tests with sand cast iron pipe extensively used for both water and gas services. Here, likewise, a full strength joint is definitely proved.

One large pipe manufacturer uses a slightly different joint. This company in casting, reinforces or thickens the ends about 30 per cent of the nominal thickness, this reinforcement extending for about 4 in. from the end, gradually tapering to the nominal pipe dimensions. A simple vee bevel is used. Many hundreds of thousands of feet have been laid and suc-

FLEXURE TEST OF COMBINED SHEAR-VEE TYPE JOINT
6" BRONZE WELDED DELAVAUD CAST IRON PIPE

Spec. No.	Description of Specimen	Bronze Used for Weld	Sectional Modulus $\frac{I}{C}$ Inches³	Breaking Load Lbs.	Modulus of Rupture Lbs. per Sq. In.
41	Plain Pipe, Class 150	....	10.4	†12,300	37,200
42	Plain Pipe, Class 150	....	10.04	†11,100	34,800
43	Plain Pipe, Class 150	....	12.07	*11,500	31,500
	AVERAGE, PLAIN PIPE				34,500
52	90° Vee, 5/32" shoulder near center of wall	Tobin	9.56	10,700	31,900
53	90° Vee, 5/32" shoulder near center of wall	Tobin	10.2	11,350	31,800
54	90° Vee, 5/32" shoulder near center of wall	Tobin	10.7	11,700	31,200
55	70° Vee, 5/16" shoulder at top about 1/16" deep	Tobin	10.15	12,000	33,700
56	80° Vee, 5/16" shoulder at top about 1/16" deep	Special	10.4	11,900	32,700
57	80° Vee, 5/16" shoulder at top about 1/16" deep	Special	9.74	12,400	36,400
62	80° Vee, 5/16" shoulder at top about 1/16" deep	Tobin	11.53	11,900	29,400
71	Same as above. Class 250 Pipe	Tobin	12.77	†13,700	33,700
73	Same as above. Class 250 Pipe	Special	13.95	†13,800	31,200
74	Same as above. Class 250 Pipe	Tobin	11.8	†12,200	32,700
78	Same as above. Class 150 Pipe	Tobin	11.25	†10,700	30,000
	AVERAGE				32,300

*Span in test 11 ft.
†Span in test 10½ ft. All other specimens tested with 9½ ft. span.
Specimen No. 55 repeatedly loaded five times to 8,000 pounds load, or to a fiber stress of 22,400 lbs. per sq. in. (20% higher than maximum strength of collar type joint) then tested to destruction. Deflection under 8,000 lbs. load, 0.34", same for repeated loadings with no permanent set.

Fig. 3

cess in service and numerous tests have conclusively demonstrated that the pipe is stronger at the weld than anywhere else.

Bursting tests have also been made to determine the tightness and strength under internal pressures. Sections of cast iron pipe have been bronze-welded together and tested to destruction with no indication of weakness at the joint. The bursting pressure for several such tests of 6-in. pipe, having slightly over 0.30 in. wall thickness, varied from 2600-2900 lb. per sq. in. pressure with the fiber stress in the pipe at rupture between 25,000-28,000 lb. per sq. in.

The cost of bronze-welding, including welding labor, is about the same as the lead bell and spigot joint or other types used for cast iron. For water lines the additional economic pressure or desirability of securing tightness may not be such an important factor as for other industries, but the use of longer lengths either double-lengthed in the foundry or

FLEXURE TEST OF COMBINED SHEAR-VEE TYPE JOINT
6" BRONZE WELDED SAND CAST IRON PIPE

Spec. No.	Description of Specimen	Bronze Used for Weld.	Sectional Modulus $\frac{I}{C}$ Inches3	Breaking Load Lbs.	Modulus of Rupture Lbs. per Sq. In.
45	Plain Pipe.....	....	15.06	†12,900	27,000
46	Plain Pipe.....	....	14.02	*12,300	29,000
47	Plain Pipe.....	....	14.55	†11,800	25,500
	AVERAGE PLAIN PIPE.				27,170
64	80° Vee, 3/16" shoulder at top about 1/16" deep.....	Tobin	14.23	12,550	25,200
65	Same as above..	Special	14.40	15,850	31,400
66	80° Vee, 1/32" shoulder near center of wall.....	Tobin	14.76	13,450	26,000
75	80° Vee with shoulder near outside.....	Tobin	13.77	‡13,300	26,100
76	Same as above..	Tobin	15.45	‡17,400	30,500
	AVERAGE....				27,800

*Span in Test 11 ft.
†Span in Test 10½ ft.
‡Span in Test 9 ft.
Specimens Nos. 64, 65, and 66 all tested with span 9½ ft.

Fig. 4

double-lengthed at some unloading point or yard, since they facilitate the speed of laying, offers considerable advantage worthy of consideration for many installations. There are certain constructions, such as bridge crossings, culverts, etc., where vibration and other factors necessitate special consideration of joining methods where the welded joint offers distinct advantage over other types. One interesting case is a 1100-ft. bridge crossing the Mississippi River in one of the large cities in the Middle West. Double street railway trackage and heavy traffic imposed very severe vibration on this bridge which led to the decision to bronze-weld an 8-in. water line. The pipe was ordered double-lengthed at the mill, since most of the mills, as previously stated, can apply double-lengths. Two 16-ft. lengths were bronze-welded into 32-ft. lengths. These lengths were welded in the field to form longer sections, rubber couplings or expansion joints being placed about every 100 ft. and at expansion joints of the bridge. A crew consisting of a foreman, three men and two welders hauled, unloaded, aligned and welded the pipe. The actual welding time per joint, including tacking, was about 35 minutes, and material required was about 2 lb. of bronze welding rod and 25 cu. ft. each of oxygen and acetylene.

One very economic opportunity for the application of bronze-welded cast iron pipe is for suction, water lines or for process piping installations where flange joints would otherwise be required. Flange joints are very expensive and all piping must be ordered to exact dimensions. It was estimated by the engineers in charge of one installation that even though only a few hundred feet of pipe were involved, a saving of $400-$500 was effected by using bronze-welded joints instead of flange pipe originally specified, and this saving was exclusive of bolting and assembly of the flange joints.

Numerous other installations could be illustrated where bronze-welding is used in construction. An unique example is the bronze-welding of cast iron casing for a deep water well for the municipal supply of water for a city in Ohio. Certain chemicals in the water had produced rather rapid corrosion in steel pipe, to overcome which cast iron pipe was substituted, and due to the dimensional limits of the well and the necessity for securing a full strength joint, the pipe was bronze-welded. All these joints being made under procedure control specifications employing the shear vee design previously mentioned.

FLEXURE TEST CHROME NICKEL CAST IRON PIPE

Four 5-foot lengths welded or coupled into 20-foot lengths tested on 19-foot span with load at center joint.

	Welded Joints*			Threaded and Coupled Joints		
Pipe Size	Breaking Load, Pounds	Deflection, Inches	Modulus† of Rupture, Lbs. per Sq. In.	Breaking Load, Pounds	Deflection, Inches	Modulus† of Rupture, Lbs. per Sq. In.
2	520	10.25	40,500	128	3.12	10,000
2½	790	8.25	33,600	396	4.00	16,900
3	1,616	8.87	41,000	1,162	5.87	29,700
4	2,370	4.06	31,600	1,661	3.18	22,200
5	3,820	3.53	29,400	2,469	2.50	19,000
6	5,602	2.50	26,200	3,250	2.13	15,200

*Welded with cast iron welding rod of same composition as the pipe.
†Modulus of Rupture based on nominal pipe dimensions.
Information furnished in Walworth Co. C. N. I. Pipe Manual.

Fig. 5

There has been introduced during the last few years a special cast iron pipe of chrome nickel cast iron which as it is cast in smaller sizes than usually obtainable and can be readily threaded and welded, is gaining extensive application for process and special industrial piping construction. This pipe is made to the dimensions of extra heavy wrought iron pipe and supplied by several manufacturers under various trade names. It has the same general chemical composition as cast iron with small amounts of nickel and chromium added, averaging about 0.50 per cent nickel and 0.30 per cent chromium. This pipe is usually cast in 5-ft. lengths, which are welded together at the foundry and supplied to the trade welded in 20-ft. lengths. Flanges may also be welded on if desired.

In the smaller sizes up to 6 in. this pipe can be cast iron welded, a little warming of the pipe being all that is required as the joint remains more or less evenly heated in the small sizes until the weld is finished. In the larger sizes, it will probably be necessary to bronze-weld. Fig. 5 shows the results of tests of welded and screw coupled joints. The strength

of the screw joint is, of course, affected by the threading, reduction in strength being proportionately larger in the thin small sizes than in the larger heavy wall pipe. The strength of the threaded joints is reduced, as might be expected theoretically, about 50 per cent, proportional to the amount of metal removed in threading. It can be appreciated from this table why welded joints are so extensively employed. As industrial installations where this piping may be used usually have ample provision for expansion-contraction and are well supported with minimum line strains, welding can be used most satisfactorily for joining.

There is one phase in the use of bronze-welded cast iron pipe about which there naturally arises some question, that is, in regard to corrosion. Individually, both bronze and cast iron are highly corrosion resistant materials, but placed together does any galvanic action accelerate deterioration? It can definitely be stated that excepting possibly strong acid or strong alkaline solutions where either of the two materials may not be suitable, experience has shown there is no deterioration at the bronze-weld over that occurring in the pipe away from the joint. Examples could be quoted of the use of the dissimilar metals as brass corporation cocks in cast iron mains, brass seats in valves, bronze-welding of both steel and cast iron service connections and other instances where no evidence of corrosion has yet occurred to give concern. But more definite proof exists. Bronze-welded cast iron pipe installations have been in service eight years in various soils and under usual corrosion conditions where judgment has dictated the use of cast iron instead of other piping materials. These have been examined from time to time where occasions have permitted. In no case has there been any evidence of accelerated corrosion at the joint, although in some cases of buried lines protective coating or paint applied in anticipation of possible trouble has entirely deteriorated.

The Development of Electric Welding in Japan

By **PROF. TAKESI OKAMOTO**

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INTRODUCTION

THE electric welding has made a remarkable progress in Japan with regards to both the researches in laboratories and the applications in practice during and after the world war as is the case for many other countries. The electric welding has found a wide field of application in dockyards, machine manufacturing works, railway workshops, locomotive and car manufacturing factories, enamel ware works, building and bridge constructions and many others for both constructional and repair work.

The electric welding has not only made a rapid progress to form a new large industry, but also promises a brilliant future development in its extensive application. Numerous research works have also been accomplished. The coating of metallic electrodes is investigated in various institutes and laboratories; especially that for cast iron by Dr. Haramiishi, Dr. Iguchi, Mr. Satoh and many others. Coatings for special steels, brass, bronze and other important metals and alloys are also investigated with success. The metallic arc welding of steel in hydrogen gas was investigated several years ago by Mr. Sasaki and Mr. Takami of the Mitsubishi Shipbuilding Co. and is applied in cases where the quality of the weld is highly estimated.

Application in Dockyards

The electric welding is now most extensively used in dockyards for building ships and constructing boilers, condensers and deck fittings. It is applied to build ships and pontoons, among which those built entirely by electric welding in the Mitsubishi Shipbuilding Co. alone are as follows:

Name of Welded Ship	Length		Breadth		Depth
Suwa-maru	110′	×	32′	×	8′
Masu-maru	45′	×	10′	×	5′
Pontoon (25 tons)	65′	×	35′	×	8′
300 tons oil barge	91′	×	26′	×	11′ 6″
Landing pontoon	52′	×	21′	×	6′
3 lumber barges	50′	×	13′	×	4′

It is also applied to construct electric welded steel masts, bilge keels, chimneys, eduction pipes for main condensers, oil and water tanks, starting air reservoirs for Diesel engines, condenser shell, mooring buoys, derrick posts, steam separators, economizer headers, superheater headers, water screen headers, boilers and condensers, chain pipes, ash pipes, ventilators, contrapropellers and other decks fittings.

The above named dockyard built many ships partly by welding and partly by riveting, for example:

Name of Welded Ship	Length		Breadth		Depth
Taigyo-maru	95′	×	20′ 6″	×	12′ 9″
60 tons pontoon	100′	×	54′	×	10′
10 tons pontoon	57′	×	26′	×	7′
6 barges	85′	×	17′	×	6′ 6″

Fig. 1 shows a landing pontoon constructed entirely by electric welding. Fig. 2 shows the welding operation of the bilge keel for S. S. Tokujyu, a ferry steamer between Korea and Shimonoseki.

The electric welding has shown its superiority in the construction of buoys; the welded buoy is, of course, completely water-tight and weighs far less than riveted one and moreover has no projecting rivet-heads, which scrape and give damage to the painted ship surfaces. Very many of them have already been constructed and those by the Mitsubishi Shipbuilding Co. alone amount to more than one hundred.

Steam condensers are also constructed with advantage by electric welding. Those for steam turbines of capacity as large as 20,000 kw. have been constructed by the above dockyard amounting to over fifty in number.

The electric welding is applied to construct derrick posts and chimneys.

In Japan, coated electrodes are mostly used, especially in dockyards. The number of metallic elec-

trodes used in the above mentioned shipbuilding company was about 1,600,000 pieces, each 368 mm. in length; the electric energy consumed for the welding amounted to about 1,200,000 kw.h. and the number of welders was about 130 in the last year.

The electric welding is applied as much in repair work as in construction. It is extensively used in repairing cracks, worn out or corroded parts, for example, rudders and rudder posts, stern frames, various parts of boilers, engines and turbines, toothed

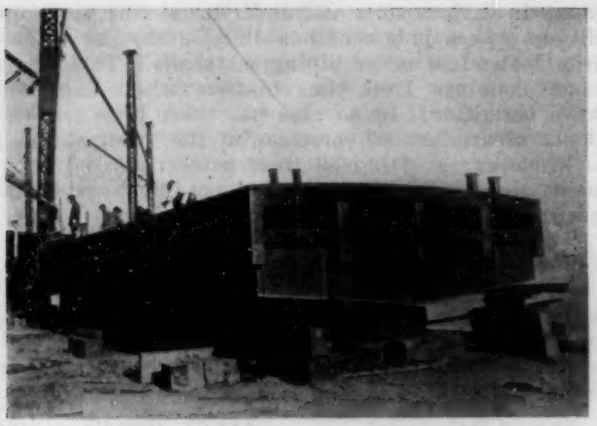


Fig. 1—Welded Pontoon

wheels, propellers, propeller shafts, chain pipes and the like worn out by wires or ropes, etc.

Application for Penstocks, Water Pipes, Etc.

The electric welding has found an extensive field of application in constructing penstocks and other pipings with steel plates. The welding of penstocks is most noteworthy and shows a good result at the pressure test and also after their erection at water power plants. Many of them were constructed by the Mitsubishi Shipbuilding Co., the Osaka Chain Works, the Nippon Electric Welding Machine Co., etc. Some of them already constructed and now in service are shown in the following list.

Electrically Welded Penstocks

Maker	Head, Ft.	Diameter, In.	Total Length, Ft.	Thickness of Plate, In.
The Mitsubishi Shipbuilding Co.	1,031	42—39	1,130	1/2—3/4
The Mitsubishi Shipbuilding Co.	667	60	2,569	5/8—7/8
The Mitsubishi Shipbuilding Co.	600	18	1,868	1/4—10/16
The Mitsubishi Shipbuilding Co.	495	58—53	307	1/2—5/8
The Mitsubishi Shipbuilding Co.	817	36	540	1/2—5/8
The Mitsubishi Shipbuilding Co.	730	45—40	1,661	1/4—5/8
The Osaka Chain Works	1,109	27	....	....
The Osaka Chain Works	630	18	....	....
The Osaka Chain Works	425	1.55 meter	....	....
		In.		
The Osaka Chain Works	760	37	....	....
The Osaka Chain Works	425	53.5	....	....
The Nippon Elec. Welding Machine Co	100	54	....	1/4—5/8

Water main pipes are also welded with success; they are used for the most part when crossing rivers. The largest one ever constructed is that across the river Muko, the diameter and total length being 45 in. and 871 ft. respectively and the whole weighing 119 tons.

Large number of beer storage tanks are now constructed by means of electric welding. They are 15 to 18.5 ft. in length, 8 to 9 ft. in diameter and 1/4 to 3/8 in. in thickness, and the total weight of these tanks built by the Kobe Works of the Mitsubishi Shipbuilding Co. alone amounted to 1050 tons.

Oil tanks (the largest one ever constructed being of capacity of 20,000 tons), water tanks, gas tanks, tanks for galvanizing iron wires, steam receivers and others are now for the most part constructed by electric welding.

No factory has ever made so much use of electric welding as sugar manufacturing factories, especially those belonging to the Taiwan Seito K. K. (the Formosa Sugar Manufacturing Co.). Mr. N. Abe, an engineer of this company, has introduced and applied electric welding to the new construction and repair of various kinds of pipings and tanks and has made it clear that electric welding can save much time and expense, especially at these factories in such remote situation as in the interior of Formosa.

It is applied to construct all kinds of tanks, steam pipes, water pipes, screw conveyors and miscellaneous steel constructions.

It is rather more advantageously applied to repair work than to new construction. It was the chief object in introducing electric welding to apply it to repairing jobs and it has been a brilliant success. Cracks and breakages at various parts of press rolls for sugar canes, toothed wheels, king bolts (5 in. in diameter) of press rolls, carbon steel roll shafts (19 in. in diameter) and others were completely repaired by electric welding. The repair works are carried on in a large scale, one of fractures of press rolls amounting even to 250 sq. in. in its surface area. In this company about 100,000 electrodes and the electric energy of about 30,000 kw.h. are used in a year.

Application in the Railway

Electric welding is extensively applied for constructional and repair works in railway workshops. In the

Fig. 2—Welding Bilge Keel

workshops belonging to the Imperial Government Railways the number of electric arc welding transformers and motor-generator sets amounts to over fifty; about 55,000 kilograms of electrodes are used and 643,000 kw.h. of electric energy is consumed in a year.

It is applied to a large variety of new constructional and repair work, too numerous to be mentioned; for example, the flanging out of locomotive boiler smoke tubes, seam welding instead of caulking, feed water heaters, superheater headers, smoke box joints, foundation rings of boilers, air reservoir of air brakes, ash pans, steam pipes, construction of totally or partly

welded passenger and freight cars and their numerous accessories, storage battery trucks, turn tables, etc.

It is also used very advantageously for repair work, for example, cracks or corroded spots of various parts of locomotive boilers, water tanks, cracks and worn-out parts of piston rods, driving wheels, return cranks, axle guards and boxes, various parts of the brake mechanism and numerous other parts of locomotives and cars.

Locomotives, cars and their accessories are manufactured also at the Kawasaki Dockyard, in Kobe, the Nippon Sharyo Seizo K. K. in Nagoya, the Kisha Seizo K. K. in Osaka and others. Almost all of steel car bodies constructed by the Nippon Sharyo Seizo K. K. are electrically welded. About 120 of such cars have been built by this company, the electrode and the electric energy consumptions amounting to 11,-200 kg. and 99,630 kw.h. in a year respectively. The Osaka Chain Works is also manufacturing miscellaneous parts of the rolling stocks, for example, gear cases of electric traction motors.

Electric welding is extensively applied to numerous purposes in street railways. It is applied to weld fish plates to rail joints, rail bonds to rails, and to repair by welding worn-out parts of railway frogs, worn-out tires, cracks and breakages of beams, side frames and numerous other parts of rolling stocks, etc.

Application in the Foundry and Machine Shop

Electric welding is applied in the foundry mainly to fill blow holes and breakages in castings and also to take or cut projections off from castings, which it is difficult or impossible to do by machining. In the Sumitomo Foundry Works, Osaka, castings thus repaired by electric welding amounted to 6500 tons last year, the consumptions of metallic and carbon electrodes amounted to 6 tons and 11,000 pieces (¾ in. x 12 in.) respectively.

Electric welding has recently found a wide field of application in the electric machine works.

Electric resistance welding is applied to weld end rings to copper conductors of squirrel cage rotors, copper wires or bars, duct pieces to core plates, protecting covers for small fans and various other purposes. Ars welding has long been used on comparatively simple constructions, for example, to weld transformer tanks and covers, oil circuit breaker tanks and covers, gear cases for traction motors and simple steel structures. Its application has recently made a rapid progress in this field and more complicated constructions are now successfully welded with considerable material and labor saving, thus decreasing the demand for castings. Stator frames for large electric machines are frequently built of steel plates by arc welding.

Miscellaneous Applications

Electric welding can be said to be available where metallic plates, bars, wires, tubes, beams, angles and the like are to be jointed to each other instead of resorting to the well-known methods of riveting or gas welding. Thus it is applicable to steel structures such as iron frames for buildings, bridges, towers and poles, cranes and the like. A factory building of the Kirin Beer Brewery Co. and the building of the Daiichi Ginko (the First Bank) in Tokyo are examples of those buildings constructed by means of both riveting and welding. The Yusen Building in front of the Tokyo Station is a remarkable example among those, which were damaged more or less by the great earthquake of 1923 and completely restored to the original state by strengthening the steel structures by means of electric welding.

In enamel work electric spot and seam welding is most advantageously used to weld various parts of tea kettles and other utensils.

In wire manufacturing works electric butt welding is made use of in order to weld trolley wires, copper wires, steel wires and bands for armoring of cables and the like.

Research Work

As we have already stated in the introduction of this paper, the research with respect to electric arc and resistance welding especially that regarding metallic electrodes, is carried out by various institutes and engineering companies.

The considerable progress in welding, in Japan, in the past few years is largely due to the cooperative efforts between the research concerns and the engineering companies to further the interests of welding.

Dr. Haramiishi, the former director of the Mitsubishi Shipbuilding Co. is carrying on the investigation of electrodes, especially those for cast iron welding with considerable success in his own laboratory. The electrode is composed of a wrought iron wire of 0.04 per cent carbon content and a special coating. The deposited metal upon a gray soft iron mass or a soft steel plate without giving any preheating shows a good penetration and contains graphite flakes just as in the ordinary cast iron, as is shown by the microphotographs of the section. He has also succeeded in manufacturing a series of coated electrodes for welding soft steel and alloy steels. It is very interesting that a steel plate or structure can be cut with a metallic electrode coated with specially treated asbestos.

In the research laboratory in Tokyo of the Mitsubishi Shipbuilding Co. the investigation of metallic electrodes for various purposes is carried on. Mr. S. Satoh, as we have already stated, has published a part of his research in regard to cast iron welding in Technical Publication No. 162 of the American Institute of Mining and Metallurgical Engineers. He has made use of a wrought iron wire as the core of the electrode and coated it with a mixture of carborundum and graphite. He has prepared a series of electrodes coated with this mixture varying the percentage of each ingredient and deposited a certain amount of each electrode upon a soft steel plate connecting the electrode to the positive terminal of the welding direct current generator. He has observed the relation between the current and the arc voltage, has taken the microphotographs of the deposited metal, has made its chemical analysis and has tested its hardness for each electrode. He has also made an elaborate experiment as to the suitable thickness of this coating. From these he concludes that the mixture, the graphite content of which varies between 40 and 60 per cent, gives the best result, the microphotograph of the deposited metal showing an ample content of graphite flakes and giving a low value of hardness. He has found that if the coating contains 1 per cent of barium carbonate added to it and if the electrodes are connected to the negative pole, they melt somewhat slowly or require longer time to melt. This phenomenon is quite favorable so far as cast iron welding is concerned.

In the Nagasaki Works of the Mitsubishi Dockyard the arc welding in hydrogen gas has been developed

by Mr. Takami and Mr. Sasaki since about 1920. They found that the weld thus obtained could be safely forged without revealing any crack, contained very few blow holes and slags and showed far better qualities with respect to the ductility, tensile strength and other chemical and physical properties than that obtained by the ordinary arc welding. They made elaborate experiments as to the properties of the welds in hydrogen gas and ascertained that this method of welding is useful when the weld is to be forged afterward or particularly good results are required.

The arc welding of brass, gunmetal and other copper alloys with special electrodes is also investigated with a considerable success.

Aluminum and its alloys are also arc welded with special electrodes with success. In the case of the duralumin welding, however, the joint becomes somewhat weaker than the original metal which has a high tensile strength, and therefore requires a proper thermal and mechanical treatment after welding.

Dr. S. Iguchi of the Kisha Seizo K. K. (the Locomotive Manufacturing Co. in Osaka) is interested in the research of electrodes for various purposes. He says that the metallic arc welding process can be classified into three kinds from the metallurgical point of view. The first of them is that with an electrode coated with a flux which generates an ample quantity of reducing gas in order to prevent the oxidation and the formation of nitrides of the deposited metal. The Kjellberg electrode belongs to this class. The second one is that with an electrode coated with a material, as for example asbestos yarn, which forms basic slag after melting. This resembles to the basic process of steel manufacture or basic open hearth process and the Quasi-arc electrode is an example of this class. The third one is that based on the principle of the acidic process of steel manufacture and the coating material forms acidic slag after melting. The electrode manufactured by him is coated with Japanese paper, special clay and metallic manganese and forms after melting an acidic slag, the chemical composition of which is as follows:

SiO_2	Fe_2O_3	FeO	Al_2O_3	CaO	MgO	MnO
44.30	9.44	16.24	20.91	3.10	1.93	4.95%

Characteristic features of his electrode are that it requires a higher arc voltage of about 30 volts than others on market when the alternating current of 60 cycles is used and the heat penetration into the base metal is remarkable, as is obviously recognized by the comparison of the cross sectional areas of deposited metals affected by the penetration.

The author of the present paper has recently published his investigation on the electric resistance welding in the Memoirs of the College of Engineering of Kyoto Imperial University, Vol. VI No. 1, entitled "Theoretical and Experimental Research on Electric Resistance Welding." Let me briefly explain the content of this paper. In the first chapter a differential equation expressing the temperature at any time and distance from the joint along the bars in the butt welding is established and its solution is obtained. This differential equation takes into consideration all the factors, which affect the temperature, for example, the power appearing on the butt surface during the welding time, the heat generated in the metal itself by the welding current flowing through the electric resistance of the metal which increases with the temperature, the heat lost by radiation and convection into the air from the surface of the bars, etc.

The electric power which appears on the butt surface can be obtained experimentally from the oscillograms of the voltage across the butt surface and the welding current. The initial value of the voltage across the butt surface is fairly small, usually about 0.5 volt in the case of steel, and this decreases pretty rapidly as the surfaces melt and come into contact.

The heat quantity thus developed on the butt surface is not so large as might be expected and the heat necessary to raise the temperature is rather produced by the current flowing through the bar, especially in the neighborhood of the butt surface, where the electric resistivity increases with acceleration as the temperature rises. In the electric resistance welding, therefore, the electric resistivity, its temperature coefficient and the thermal conductivity of the metal play an important rôle. Numerous oscillograms show simultaneous changes of the welding current and the voltage across the butt surface and also of the voltage between the bar and the clamping block and that across the butt surface.

The author calculated the change and distribution of temperature at various points along the bars for a case of butt welding of soft steel bars of a diameter of 1 cm. and welded with a welding time of 4.4 seconds, and expressed these results with curves. The part of the welded bar several millimeters apart from the joint is put fairly long under the influence of an annealing temperature and accordingly becomes somewhat soft and shows a contraction of the cross section and often an ultimate breaking at the tensile strength test. Thus the distribution and change of temperature have not a small effect upon the microstructure and also the physical properties of welded bars. These facts are fully explained by the change of hardness and the microphotographs at various points along the bars.

As is evident from the oscillograms, the voltage between the bar and the clamping block remains almost constant throughout the welding process and its magnitude is usually greater than that across the butt surface, and also depends largely upon the conditions of the outer surface of the bar. It is about 0.5 volt for ordinary soft steel bars and is often less than 0.3 volt for those with the polished surface. This voltage drop occurs at both sides of the joint and the power or heat loss due to this is fairly large. The further calculation shows that a part not smaller than 50 per cent of the power input of the welding machine is wasted as this loss and that in the welding transformer.

The author welded soft steel bars of various diameters under various welding conditions, namely, varying the welding time, the spring pressure and the travel, and found the most favorable conditions in order to get good welds. The result of the tensile strength tests and the metallographical study of the welds has led the author to the following conclusions. The welding time must be made as short as possible, especially when the diameter of the bar is small. The pressure of the spring which presses one of the bars against the other must be kept as large as possible. If the spring pressure is large enough, the welding time may be made somewhat longer without reducing the tensile strength. The travel or the distance through which one of the bars is shifted toward the other by the spring pressure at the end of the welding operation has no appreciable effect on the properties of welds, if it is not too small.

The percussion welding can be regarded as a limit-

ing case of resistance welding, where the welding time is made very small, even smaller than one hundredth of a second in order to prevent the oxidation of the metal and to concentrate the heat within the immediate neighborhood of the butt surface. By this process metals that are liable to oxidation, such as aluminum, can easily be welded, and moreover metals of different materials or dimensions can be successfully welded if the combination of two materials be suitable.

If two wires of different materials are welded the heat quantity developed between two butt surfaces are divided into two wires in proportion to the square root of the product of the thermal conductivity, the specific heat and the specific gravity of the respective material. The heat quantity appearing on the butt surface can be obtained from the simultaneous oscillogram of the impulsive welding current and the voltage across the butt surface, and hence the change and distribution of temperature can be calculated by evaluating the expression of the temperature. The further deduction shows that the temperature at some small distance from the butt surface for one of the wires is higher than that for the other, if the value of the thermal conductivity divided by the product of the specific heat and the specific gravity of the former is larger than that of the latter. If a good weld be desired, these temperatures must be higher than the melting points of the respective metals, and therefore the above mentioned value and at the same time the melting point of one of the metals must be larger than those for the other.

The physical constants of metals and alloys are tabulated and the weldability of any combination or pair of two metals or alloys can easily be judged from this point of view.

The author welded many combinations of metals and alloys and took the microphotographs of the joints and ascertained that this theory of percussion welding is proved to be true.

Aluminum and copper are one of the combinations most favorable for the welding and accordingly the boundary between two metals is very irregular showing a good melting and intermingling of both metals. On the other hand, the joint of aluminum and iron which form an unfavorable pair, shows a distinct line of demarkation as if molten wax were dropped on a metallic surface, thus making a weak joint. Numerous combinations of metals and alloys were welded and their microphotographs were taken and they were tested with regard to the tensile strength and also to the ability for the wire drawing.

Texas Bridge Features Arc Welded Battleship Deck Floor Construction

By A. F. DAVIS

✦ Mr. Davis is Vice-President of The Lincoln Electric Company.

A NEW and unusual type of bridge construction which involves the construction of an arc welded battleship deck floor was recently demonstrated with the completion of a bridge over Taylor Bayou in Jefferson County, Texas.

This new bridge consists of a swing section 161 ft. long which is now complete, and two approaches, one 134 ft. long, and one 96 ft. long, which are to be constructed in the future. The swing section was constructed by the Coastal Construction Company of Orange, Tex. The bridge forms part of a highway between Port Arthur and Galveston, Tex., and spans a bayou near the Gulf of Mexico at West Port Arthur, Tex. It was constructed to conform with the State Highway Standards, that is, to maintain a live load of 150 lb. per square foot, and a dead load of 15 tons.

The floor of this bridge is fabricated of ½-in. Diamond floor plate arc welded into place, as shown in Fig. 1. The swing section covers an area of approximately 3220 sq. ft. and is fabricated of plates 20 ft. long by 4 ft. wide. These plates are spaced ½ in. apart for arc welding to the flanges of the floor beam. The roadway is 18 ft. wide and on the sides the plate turns up a distance of 1 ft. to form the curb. This makes the roadway a U-shape, as shown in Fig. 1. The floor is made strong and rigid by arc welding the plate to the flanges of the floor beams on the under side with fillet welds 3 in. long, spaced on 9-in. centers.

The arc welding on this bridge floor was done with the shielded arc which produces welds which have superior physical qualities.

The under structure of this bridge consists of two plate girders on either side and eight longitudinal floor beams. The plate girders are built up from

Fig. 1—Arc Welding the Floor Plate into Place on the Floor Stringers

5/16 and ⅜-in. plate and 5-in. by 4-in. angles, with ⅜-in. plate 18 in. wide tack welded to the angles to form the flanges. At the center of the bridge this girder is 6 ft. deep, at the ends of the swing section 30 in. deep. All permanent stiffeners on this girder are arc welded into place. The floor beams on the bridge are 18-in. 52-lb. I-beams, and the stringers are 10-in., 21-lb. I-beams.

The proposed approaches to this bridge are to be completed in the future. The existing approach on the north side is 88 ft. 7 in., while the proposed approach is 96 ft. On the south side the present approach is 136 ft. 5 in., while the new one will be 134 ft.

New Pipe Fittings for Welding

By **S. L. BARBER**

✦ Mr. Barber is Manager of Forge Sales of the Taylor Forge & Pipe Works, Chicago.

OUR company has developed a complete line of seamless steel pipe fittings for welding consisting of elbows, tees, reducing tees, bull plugs and reducing nipples, as well as forged steel butt welding flanges which have already been on the market for over three years. All sizes up to 24 in. are available. The tees are made in sizes 2 in. to 8 in.

This line of seamless pipe fittings for welding is unique in many respects. It permits entire pipe systems fabricated by welding to be installed with only the use of true circumferential welds acknowledged to be the easiest to make, resulting in increased efficiency of the welder, and full strength welds. Erection is considerably simplified. These fittings are lighter in weight than cast steel fittings, and therefore require fewer and lighter supports. They require less space in erection, and in addition, permit easy and economical insulation. The manufacturing methods are on a mass production basis employing patented processes to a great extent. The elbows are made without thinning or buckling of the walls, and further have the advantageous feature of short tangents to facilitate welding and accurate lining up. Elbows are made of the standard center to end measurement of American Standard Extra Heavy Screwed Fittings, and with end to center to end dimension equal to one and one-half times the nominal pipe diameter. The ends are machine tool beveled; this is true of all our forge fittings. Machine tool beveling provides a smooth, clean surface for welding, and assures maximum accuracy as well as installation ease.

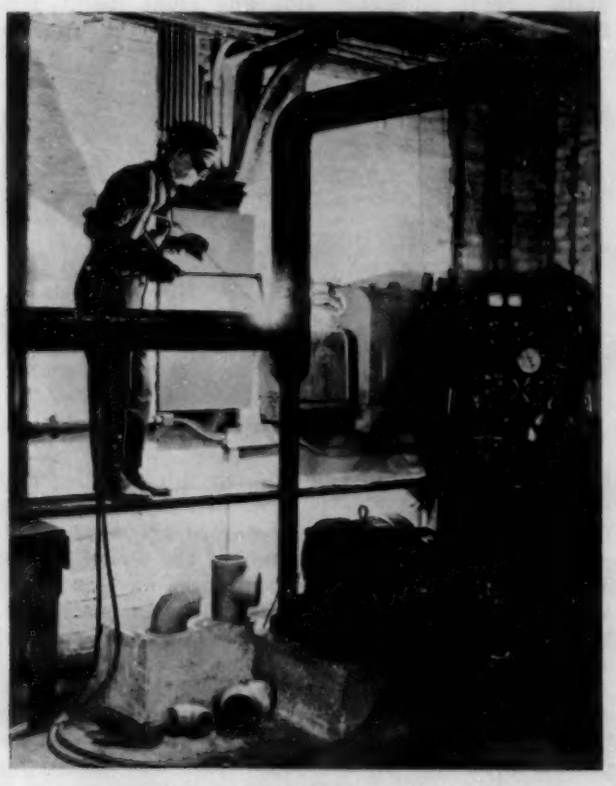


Fig. 1—Welding Fitting into Place

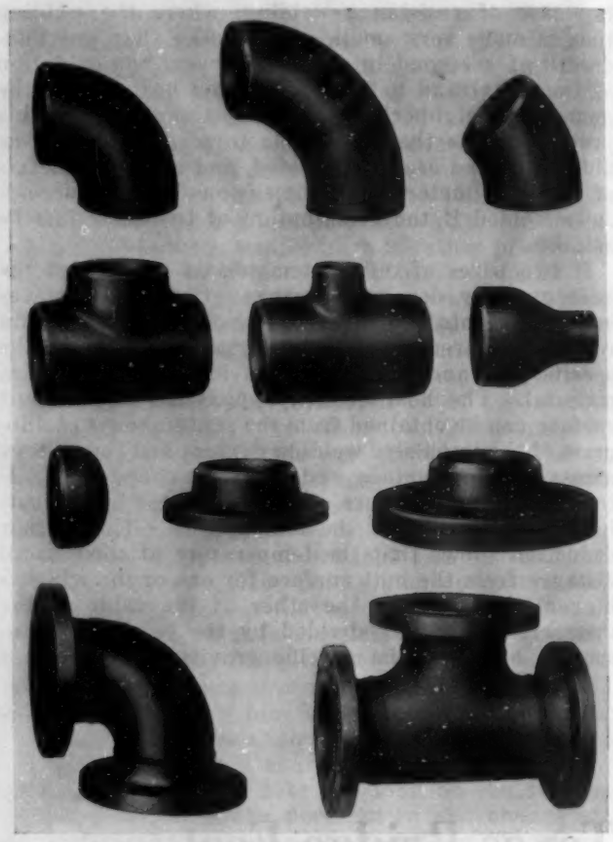


Fig. 2—Fittings Designed for Welding

These forge tees are a forged tubular product not to be confused with forged steel tees made solid and drilled out which have been on the market for many years. The tees are made to pipe thickness at the ends, with the body thickened up especially around the outlet to give required reinforcement. The basis of design for the tee, as well as the other welding products, has been to make the fittings of an installation of welded fabricated pipe the strongest parts of the line. Flow or friction has also been carefully considered in design. The tees have sweep outlets, a feature especially important for lines of high velocity.

It is expected that with forged tees now available, the former practice of welding one pipe into another to form a tee will be eliminated.

The reducing nipples are designed especially for welding, with the length sufficiently long to aid installation, yet shorter in dimension than that of the screwed reducing nipple. The smooth, well-balanced shape of the reducing section assists materially in fostering easy and unimpaired flow. The bull plugs are forged under the most approved forging conditions; formed to an ellipsoidal shape to withstand end pressure; and made with a surplus of straight section to enable easy and simple attachment to pipe. The butt welding flanges, providing for the insertion of valves in welded pipe installations, have a long fillet at the hub to prevent distortion.

Welding of Structural Steel

By **J. E. FERGUSON**

✦ Paper presented at April meeting of A. W. S., Chicago Section by J. E. Ferguson of the Austin Company.

IT is not my intention to repeat a lot of technical data and statistics for Fusion Welding with which most of you are familiar. You have learned considerable about Steel Welding from articles written lately on this subject and from specifications and discussions within your own group.

In relation to this subject of Welding Structural Steel, I do want to tell you about some things which will materially help the development of welding.

While arc welding has been used for some time in welding different kinds of mechanical and semi-mechanical products, tanks and so on, it is only comparatively recently that welding has commenced to be used successfully in the field of structural steel work.

It was about ten years ago that the Austin Company became convinced that welding was a good method of forming connections for structural steel members. The connections were thus formed by welding instead of riveting.

Very early in our experiments it was evident that welding presented a good method of fabrication if properly done.

At that time, after much research work and many tests, it was clearly shown that the strength of welded joints was comparable to the strength of riveted joints.

Among the tests conducted to determine the strength of welding was the testing of a full size welded truss along with a riveted truss. Like some of the other tests this one showed to the advantage of the welded truss, the riveted truss failing first.

Another very good test of welding was made in a building erected for the Pittsburgh Transformer Company about six years ago when in this building one large built-up plate and angle column for a 15-ton crane runway and one plate girder for a runway carrying a 50-ton crane were completely welded instead of being riveted. The fact that these members have continuously taken care of the loads without any apparent distress, over this period, is sufficient and ample evidence of the strength of welding.

As time progressed and my company continued to carefully study and develop this new method of fabrication, there was some advertising propaganda broadcast from certain sources which did not in any way help or advance welding, on the contrary did more to hinder its progress.

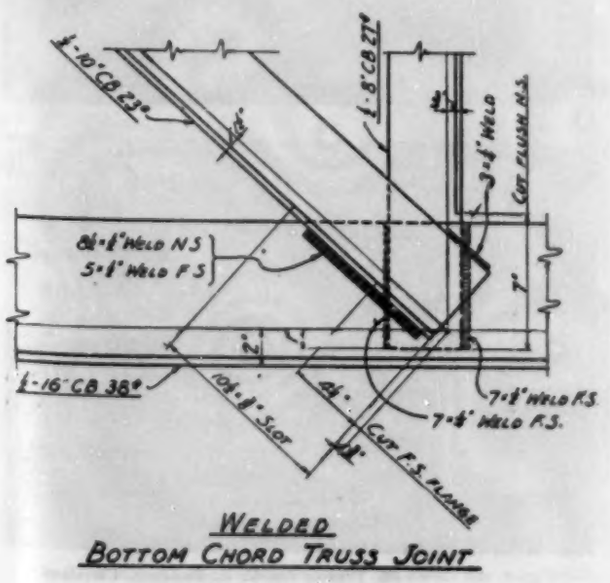


Fig. 1—(Patent Applied For)

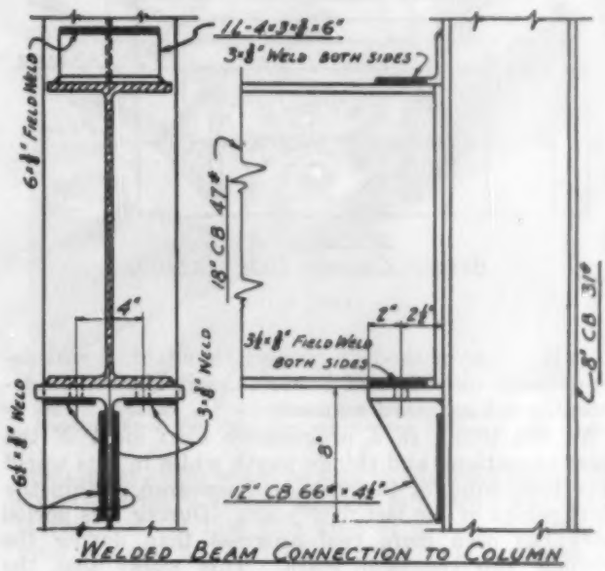


Fig. 2

When you stop to consider the importance of a bridge or a building, and realize the amount of knowledge and skill necessary to develop such a structure so that it will be the safe structure required for public use, it can be realized what careful thought and painstaking development are necessary to attain the proper result.

To illustrate what I mean, you will probably recall, a few years back, some enthusiasts of the welding method even went so far as to advocate that building frames be fabricated and erected at the site without any shop fabrication and even without proper drawings.

Presumably all that was necessary was the desire for a building, the site, steel shipped direct from mill to site, a couple of welding machines with welding operators, and presto the building would assume its form.

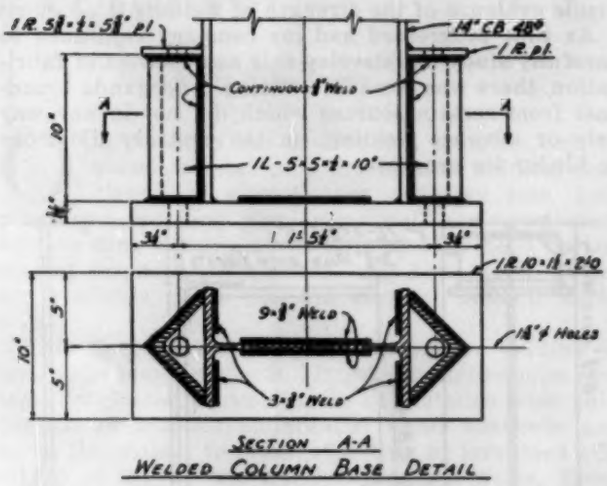
Of course the thinking person, the architect, engineer and the responsible construction company know that this is far from the right method to pursue.

I do not mean to confuse what has just been stated with some few cases of simple beam and H column buildings in certain localities which have been constructed by responsible builders in the field where the fabrication was simple, the proper design was made and the proper detail drawings furnished for the welding.

Even these simple cases, however, must be analyzed

carefully from a cost standpoint to see whether the finished work is actually as cheap as when the prescribed method of welded fabrication and erection is used.

Later I will tell you more about the proper method of fabricating welded structures. An important point I want to make here is that while the welding of



SECTION A-A
WELDED COLUMN BASE DETAIL

Fig. 3

steel is a new method, if properly handled, it will develop much quicker and better than if allowed to develop in a haphazard manner.

We are living in a progressive age: most of the great inventions and things worth while in this world have been brought to light, or discovered, within the short period of the last fifty years. During this period there has been more real progress than during the previous two thousand years. This shows that the world today is in a receptive mood for new methods. Ideas properly conceived and developed will be received favorably.

Riveted structural steel work is quite an old method of operation and has done much to promote progress during the last two generations.

It must be remembered that the riveting method had to be carefully developed to satisfy Engineers, codes and other conditions.

In riveted work the design is carefully worked out, detail shop drawings made with every rivet and hole shown, and these designs and details satisfy and pass existing codes. During and after fabrication in the shop proper inspection is made to insure rivets of proper strength and according to drawings.

The field work also requires the same careful handling and inspection by competent men.

So it is with the new method of "Welding": the same careful operation and inspection are required to not only make the finished structure what it should be, but to inspire the necessary confidence for the quicker development of Welding.

During the past three years many important structures have been welded.

Up to the present time welding has been successfully used in the fabrication and erection of some eighty important buildings, about twenty bridges including railroad bridges which carry locomotives and cars, also electric traveling cranes, and in some cases steel barges and ships, thousands of miles of steel pipe and other numerous structures and products.

Some of the advantages of welding are:

1. Silent construction.
   This feature has particular advantages in congested areas or in the neighborhood of hospitals, hotels and residences.
2. Welding will appeal to most progressive owners as the most modern method of fabrication and erection. The finished work presents a neater, smoother and cleaner appearance.
   In trusses the lines of the chords and web members are unmarred by large and unsightly gusset plates as well as innumerable rivet heads.
3. Welded steel offers an excellent avenue to reduce costs, both in the fabrication and erection. There is a substantial saving in weight on account of the possibility of more economical distribution of material.
4. Welded steel gives a stronger and stiffer construction. Welded trusses, although lighter than riveted trusses designed for the same loading, are stiffer and easier to handle in the shop and field. The difference in stiffness between a welded crane girder bridge and one fabricated by riveting is very noticeable when standing on the crane in motion.
5. Welded steel offers opportunity for simplification of design and detail of members.
   An example of this is in the truss, the gusset plates are eliminated and the web members welded directly to the chords.
6. Additions can be made to existing structures and members may be strengthened easily by the welding method. Many railroad bridges have been strengthened to take care of the increased live loadings. This would be a big task and much more costly if done by riveting.
7. The accident hazard during erection is greatly reduced by the absence of falling rivets. On some buildings this has been quite serious.

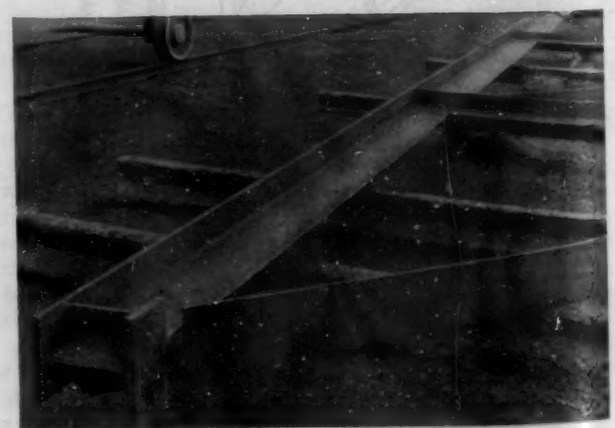


Fig. 4 and 5—80-Ft. Trusses for G. E. Building, Cleveland (Patent Applied For)

8. The fire hazard is reduced by the elimination of hot rivets.
9. Alterations caused by errors or changes are more easily made.
10. Welding requires more simple and less expensive stagings than for riveting.

Welding will be advanced by

1. Proper codes for cities and towns.
2. Education of architects, engineers, fabricators and construction companies, in the advantages of welding.
3. Proper methods of fabrication, erection and inspection for welded steel.
4. The reception of welded steel by owners and the public.

We will first consider Proper Codes for Cities and Towns.

At the present time some one hundred cities of this country have changed their codes to cover the welding of steel structures.

In other cities, where codes have not yet been changed, welding is made possible by the building commissioner using his discretionary powers under the building law, which allows the use of new materials or methods under such regulations as the commissioner may fix. The office building for the Edison Electric Illuminating Company in Boston was field welded in such manner.

In this case the requirement fixed was that the Consulting Engineer should certify by affidavit that the building as pertains to the welding should conform to the stresses and strains required by law, and that at the completion of the welding should certify by a final affidavit that the building does conform.

As a Welded structure, in the same manner as a Riveted one, requires much expert knowledge and experience of the men handling the work in its design, manufacture, erection, inspection, and especially in setting up the requirements for these different phases of the work, the progress of Welded structures has been obviously delayed on account of not having a code in many cities and towns embracing this new method of constructing buildings. The excuse for the delay may be that it is somewhat difficult to have the proper men in city and town organizations, not only to prepare a good and suitable code for welding steel structures, but also to have men to know that such requirements are intelligently and properly carried out.

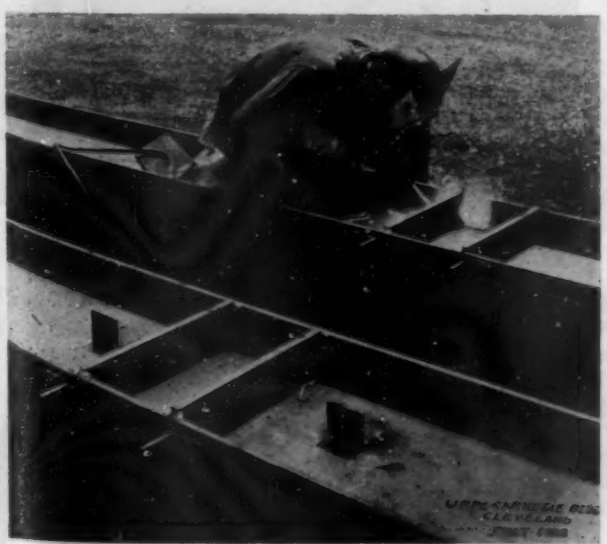


Fig. 6—Welding a Continuous Beam for the Upper Carnegie Building, Cleveland

An excellent and thoroughly safe way for a city to permit Welding of steel structures is to adopt Welding in its code in accordance with a first class standard code for Fusion Welding. A logical code of this kind would be that of the American Welding Society.

By adding to their building codes in this manner a great many cities would be able to go ahead with Welded structures much sooner than in any other way, and it is very certain that this kind of a code would be as good as could be obtained. Such a code would be kept up-to-date as far as concerns Welding.

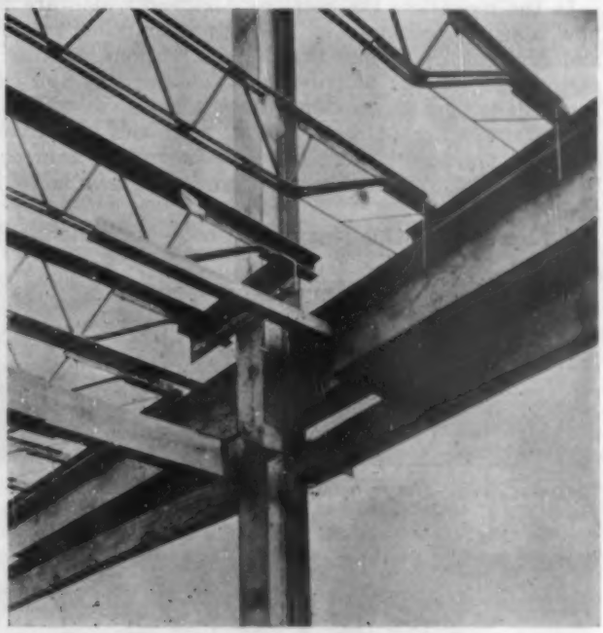


Fig. 7—Columns and Continuous Beams for the Upper Carnegie Building. Steel Was Fabricated and Erected Without a Hole or Bolt

A big help in promoting the Welding method of construction will be for the cities and towns to have a proper code embracing this method.

Most progressive architects, engineers, and construction companies are quick to perceive the advantages of this new method providing they can satisfy themselves that the work can be carried out without any more trouble than is experienced in that of a riveted structure.

With a suitable code permitting welding, and with the right kind of fabrication and erection, any doubt will be removed and there will be very little opposition by progressive architects, engineers and construction companies.

The consideration of the next item mentioned, which will promote the use of welding of structures, is that of "proper fabrication and erection." This is probably the most important of the four mentioned.

The proper fabrication of welded steel includes:

1. The use of correct sections.
2. Logical designs for this particular use.
3. Suitable details for welding.
4. Right kind of plant layout.
5. Right equipment, particularly welding machines, grids, jigs and handling equipment.
6. Proper kind of organization, including welding operators—
   Suitable training of welders.
7. Proper inspection.

At the present time the rolling mills are not able to

furnish all of the sections of steel required for the most efficient an economical design of welded steel work.

In time the rolling mills will roll some of the sections more suitable for welded steel work. This will be done when the demand is sufficient to warrant the installation of the new rolls required.

In the meantime the sections designed which are not now rolled are obtained by taking proper rolled sections and dividing these into the desired sections. Large T sections for chords of trusses are obtained by splitting broad flange eyebeams along the center line of web.

The designing of welded steel members is entirely different from the design of riveted members and must be considered on this basis if any progress is to be made.

An example of this is a roof truss. For welding the

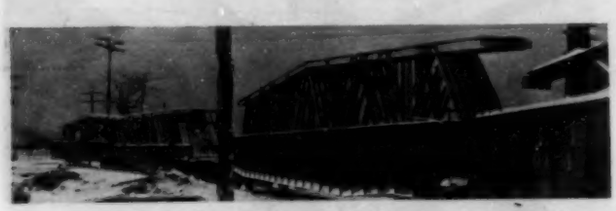


Fig. 8—Carloads of 70-Ft. Welded Trusses for Simmonds Saw & Steel Co. Building, Fitchburg, Mass.

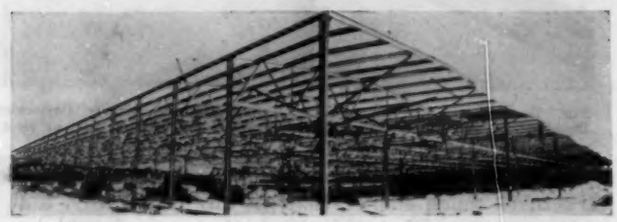


Fig. 9—Welded Steel for Simmonds Saw & Steel Co. Building

most economical design usually calls for a large tee section for the top and bottom chords with either angles or smaller T sections for the web members and all of the gusset plates are usually eliminated. A design of this kind will save on the average of from fifteen to twenty per cent, or even more, in the weight of the truss.

It is just as necessary to make the proper detail shop drawings as to have the proper design. The proper sections and details must be used to give an efficient and economical member. Also in the same manner that every dimension, rivet and hole are fixed in a riveted member so must every dimension and weld be fixed for the welded *piece*. The weld is figured from the stress and the length of weld is specified together with the size of the weld bead.

For the actual fabrication of the work in the shop it is essential to have the proper plant layout so the steel can move in a straight line of production from the receiving yard through the cutting, layout, punching, assembling and welding departments and through to the inspection and shipping yard.

On most contracts of any size, there is some duplication of the members to be made. In such cases the members can be manufactured in jigs, which expedites the assembling of the pieces. A jig may be self contained or be a member of itself, or it may be built up on the grid where the welding is done. The intelligent use of jigs in assembling gives a product which is accurate to dimensions and reduces the cost of manufacture.

It is important that the welding department be furnished with the proper handling equipment, welding machines and accessories suitable for the work to be done, and that this department be carefully supervised to see that operators are using the correct current, polarity, right size and kind of welding wire, etc.

In our plant, in addition to the regular so-called hand welding machines, we use semi-automatic machines which give good results for some classes of work.

While I am not going to repeat data from specifications and technical requirements for the actual welding, I will tell you something about the training of operators, their handling and supervision in making welds and the inspection of welds.

Care must be used in selecting proper operators. Just because a man has done welding for several years does not mean he is a good welder.

At our plant we prefer to make our own operators. This is done by giving the man a suitable course of training in welding which extends over several weeks time.

Before an operator is used for welding production work he has to pass certain prescribed tests. These include tests given in standard specifications which include bending and pulling tests. After starting as an operator, at prescribed intervals the operator is given further tests to insure workmanship of the proper standard. Careful supervision will insure good smooth looking welds of the proper size, dimensions and strength.

Every weld is carefully inspected to see that it is according to the drawing and up to specifications in every way. Our own shop inspector carefully examines all the welds. For structural work the visual inspection, supplemented in some instances by the hammer test, is all that is necessary to insure the proper strength of the welds.

In erecting the steel in the field, the steel members are placed in position in the same careful way as in a riveted structure. The members are held in position by the use of bolts and after these bolts are tightened the structure is carefully plumbed and is then ready for the field welding.

As in the shop welding, it is just as important to

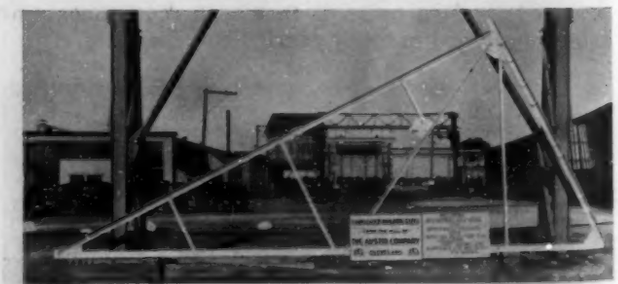


Fig. 10—Jig for Assembling Sawtooth Trusses for Welding

Fig. 11—80-Ft. Welded Trusses for G. E. Cleveland Building

Fig. 12—Shop Welding Steel for G. E. Fort Wayne Building

carefully choose the proper operators. The operator should be properly qualified by making test pieces and having these tested. Also, at certain stated intervals, tests should be taken from all the operators to insure proper welds.

It should not be necessary to do any overhead welding, and this should be avoided to get the best grade of work. As the welding progresses, each weld should be inspected by a competent inspector and in the same manner as described for the shop welds.

For this inspection the services of an inspection bureau can be used to advantage. As in the shop inspection the visual inspection of each weld will usually suffice, and in some cases the hammer test may be used to supplement and verify the visual inspection.

One of the important requirements for the proper grade of welding is that the actual work be performed by a thoroughly responsible company. This has been inferred but not specifically mentioned. It will insure good work because the responsible company not only knows what is necessary to get the proper results, but will see that the successive steps and operations are actually and properly carried out to produce good work and construction.

Finally, when we have the codes of cities and towns embracing welding, progressive architects, engineers and construction companies considering welding on at least an equal basis of riveting, and the fabrication, erection and inspection performed on the basis just described, it will follow as the night follows the day that welded steel will be quickly and universally accepted by the owner and the public, and we will have welded structures rising in all sections of the country. Welding of steel will then take the place in the world affairs it deserves.

For Repairing Old Oil Lines

By V. H. VAN DIVER

✦ Mr. Van Diver is connected with the Linde Air Products Co.

IN view of the splendid record that has been established by the use of welded joints in pipe line service, it is highly desirable that welding be used for repairs when breaks develop in operating oil pipe lines.

The first step in repairing such a break is to uncover the pipe for a distance of 200 ft. across the break to permit lifting the line so as to weld above the ground level. This is good practice for welding and insures having additional slack in the line when relaid.

If the break does not extend clear through, it is best to cut the pipe with mechanical cutters at such a point that a clean edge will be obtained on one end of the pipe. The line should then be drained and if practical to do so, the oil should be stored nearby so it may be returned to the line. In any case, the oil that has spilled onto the ground must be cleared away in the immediate vicinity of the break and all of the oil-saturated dirt must be removed before any welding is done. This is generally an easy job as the oil soaks into the ground only 2 or 3 in. even when it has stood for several weeks.

The end of the pipe that does not have the broken place, having been cut mechanically, is ready to have the new piece of pipe joined to it. The first step is to make sure that no oil will run out during the welding, so the pipe is carefully drained and a mud dam is built about a foot back inside the old pipe.

The welding operation is simple as the piece being added is usually short, say 4 or 5 ft. in length, although at times an entire length of pipe must be replaced due to a split or to excessive corrosion. The procedure for making a tie-in weld is followed.

If spilled oil is to be returned to the line it will also be necessary to weld a 2 or 3 in. branch into the main line.

After the first weld has cooled the mud dam should be picked out and both sections of the line should be drained. Both ends should then be raised above the ground level and placed on skids. The section of the line having the broken or damaged place should be marked to match with the end of the new piece just welded to the other part of the main line. After cutting at the proper point the ends of both sections should be plugged with mud dams.

Then the ends should be lined up and tacked for a position or tie-in weld. After this weld has been made and allowed to cool the line should be crowded back into the ditch thus assuring adequate slack or compression.

This is the best time to return the spilled oil to the line as the pressure will be low. To do this, the discharge of a portable oil pump is connected to the 2 or 3-in. branch previously welded to the line.

When breaks occur in pipe lines through some unforeseen circumstances, it is a simple matter to make repairs quickly by the oxy-acetylene process if the above correct practice for doing this work is observed.

Building-Up Welding Fittings on the Job

By MR. FRED S. DURHAM

✦ Vice President and Treasurer, Bonney Forge and Tool Works.

PIPE welding, until recently, was limited to long runs. These installations were mainly used as low pressure carriers for liquids such as oil and gasoline and similar products and for transporting gas for illuminating and power purposes. The welding and laying of these lines were carried out under difficulties because there had been little or no development of welding fittings for making tees, crosses, side-outlet tees, etc. In fact, it is only within recent months that there has been any type of welding fitting on the market.

Now, industries everywhere are more and more realizing the decided advantages of welded piping, and this, coupled with the above, is of necessity creating an acute demand for satisfactory welding fittings.

Fig. 1—Tacking Branch to Weldolet

The branch pipe is firmly tacked to the outlet opening of the weldolet, to hold it in the desired position. The operator makes a fusion or Vee weld, puddling it well to produce a strong, leak-proof joint. The welding surface is beveled at an angle of 45 deg. To produce a 90-deg. Vee weld, the end of the branch pipe should also be beveled at 45 deg.

Weldolets and thredolets are welded fittings designed to fill the need for making branch connections, such as tees, side-outlet tees, crosses, double-crosses, etc. Very strong and durable branch connections are made with these products, by merely tacking them to the parent pipe, then puddle welding along the vee edge, cutting out the section of pipe inside the outlet of the fitting and, as the case may be, welding or screwing the branch in position.

The old method of doing this was to cut and form a hole in the main pipe, using a templet, then beveling the end of the branch pipe to fit the hole as nearly as possible. The branch was then welded to the main trunk and the junction completed. Naturally, there were many difficulties encountered in doing this accurately and in a satisfactory manner. Frequently the main pipe buckled or warped. In many cases it was impossible to cut the hole accurately or the branch pipe did not fit closely, with the result that large quantities of welding metal had to be deposited at the line of junction; this did not form a satisfactory joint. Even if the work was done carefully and well, the best that was accomplished was a sharp turn from the main line into the branch, which produced turbulence and friction, and restricted the flow.

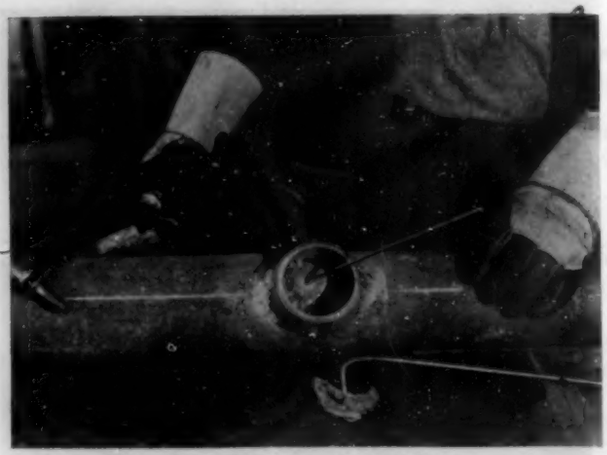


Fig. 2—Removing the Button

Tests show that the best practice is to first weld the weldolet directly to the main pipe, and then remove the button, as illustrated at the left. An "S" shaped cut is made across the diameter of the hole, and the button removed in two sections. Welding wire is tacked to each section before cutting to facilitate its removal. A clean, unobstructed outlet results, and there is no forming or cutting to templets necessary

Weldolets and thredolets overcome these difficulties. They are placed on the parent pipe in the exact location and at the angle at which the branch is to be taken. They are tacked and welded fast without disturbing the pipe or weakening it by first cutting the hole. After the fitting is welded, an "S" shaped cut is made inside the outlet of the fitting. The heavy construction of the fittings prevents any distortion or weakening of the main pipe even after the button has been removed. The reader will readily see that the funnel-shaped outlets reduce friction and turbulence when the joint is completed; and also that an "S" shaped cut permits removal of the button in two pieces.

An important advantage not to be overlooked is the beveled vee edge along the surface of the fittings, which comes in contact with the parent pipe. This vee edge brings the fitting in close contact with the parent pipe and allows the use of the most improved fusion or vee weld, which, as is well known, is the strongest and simplest type of weld for this work.

These products also allow the most flexible type of welded pipe construction For example, a straight pipe, without disturbing it, may have welded on it at any angle from horizontal a fitting to form a right-angle branch. Opposite, or at any location on the other side of the pipe, may be placed another fitting to form a second right-angle branch. Thus an offset cross, or straight cross is produced. A third weldolet may be introduced at an angle of 90 deg. to this cross to form a side-outlet cross. Opposite this may be placed another, either in line with the above fittings or offset from them.

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